APPENDIX C.9

FACILITY DISPOSITION MODELING

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C.9 Facility Disposition Modeling

C.9.1 INTRODUCTION

This appendix describes the methodology and results of the fate and transport modeling that DOE performed as part of its analysis of the facility disposition alternatives. As discussed in Chapter 3 of this EIS, DOE considered multiple conditions in which the facilities could be readied for ultimate disposition. Some of these alternatives would result in an estimated amount of residual radioactivity and nonradiological constituents that would remain in the facilities after disposition and would be leached to the environment at some point in the future. The analysis in this appendix applies to INTEC HLW facilities (current and proposed). Assessment for facilities other than HLW is beyond the scope of this EIS. Section 5.4 of this EIS presents the long-term INTEC cumulative risk, including previous facility closures and decisions to be made in the Operable Unit 3-13 Remedial Investigation/Feasibility Study (Rodriguez et al. 1997). Any future environmental restoration or facility closure actions at INTEC would consider the long-term risk presented in this EIS.

As discussed in Section 3.2 of this EIS, DOE identified the following alternatives that could be implemented for disposition of some or all of the INTEC facilities:

- No Action
- Clean Closure
- Performance-Based Closure
- Closure to Landfill Standards
- Class A and Class C Grout Disposal
  - Performance-Based Closure with Class A Grout Disposal
  - Performance-Based Closure with Class C Grout Disposal
  - Disposal of Class A Grout in a Low-Activity Waste Disposal Facility
  - Disposal of Class C Grout in a Low-Activity Waste Disposal Facility

Implementation of any of these alternatives would have short-term impacts that are evaluated in Section 5.3 of this EIS. Long-term impacts of these alternatives are evaluated in this appendix and are based on the following assumed activities associated with the alternatives:

No Action – In the No Action waste processing alternative, the calcine in the bin sets and the liquid sodium-bearing waste in the Tank Farm would not be processed and would remain in those facilities.

During the period of active institutional control through 2095, surveillance and maintenance necessary to protect the environment and safety and health of workers would be performed in the normal course of INTEC operations. Beyond the period of institutional control, these materials could migrate into the environment.

Clean Closure - Under this alternative, facilities would have the hazardous wastes and radiological contaminants, including contaminated equipment, removed from the site or treated so that the hazardous and radiological contaminants would be indistinguishable from background concentrations. Clean Closure could require total dismantlement and removal of facilities. Use of the facilities (or the facility sites) after Clean Closure would present no risk to workers or the public from contaminants from previous activities.

Performance-Based Closure - Closure methods would be dictated on a case-by-case basis depending on risk associated with radiological and chemical hazards. The facilities would be decontaminated such that residual waste and contaminants no longer pose an unacceptable exposure or risk to workers or to the public. For the Tank Farm and bin sets, DOE anticipates using a specially engineered grout mixture to be placed in these facilities as a stabilization method. The grout would be designed to provide favorable characteristics that would provide long-term structural support and that would bind contaminants to reduce leaching to groundwater.

Closure to Landfill Standards - The facility would be closed in accordance with the state and federal requirements for closure of landfills. Closure to landfill standards is intended to protect the health and safety of the workers and the public from releases of contaminants from the facility. This could be accomplished by installing an engineered cap, establishing a groundwater monitoring system, and providing post-closure monitoring and care of the waste containment system, depending on the type of contaminants. As with the Performance-Based Closure, DOE anticipates using a specially engineered grout mixture to be placed in these facilities as a stabilization method for the Tank Farm and bin sets. The grout would be designed to provide favorable characteristics that would provide long-term structural support and that would bind contaminants to reduce leaching to groundwater.

Class A and Class C Grout Disposal - As discussed in Chapter 3 of this EIS, several of the waste processing options would result in production of a low-activity waste stream which would then be grouted and disposed of in (1) a near-surface disposal facility on the INEEL, (2) an offsite disposal facility, or (3) the Tank Farm and bin sets. Based on its content, the grout would be categorized either Class A or Class C low-level waste and would contain residual radioactivity that could be leached to the groundwater. For purposes of analysis in this appendix, DOE considered the following alternatives for onsite disposal of this grout:

- Performance-Based Closure with Class A Grout Disposal – The facilities would be closed as described above for the Performance-Based Closure Alternative. Following completion of these activities, the Tank Farm and bin sets would be used to dispose of Class A grout produced under the Full Separations Option under the Separations Alternative.

- Performance-Based Closure with Class C Grout Disposal – The facilities would be closed as described above for the Performance-Based Closure Alternative. Following completion of these activities, the Tank Farm and bin sets would be used to dispose of Class C grout produced under the Transuranic Separations Option under the Separations Alternative.

- Disposal of Class A Grout in a Low-Activity Waste Disposal Facility – The Class A grout produced under the Full Separations Option under the Separations Alternative would be placed in a low-activity waste disposal facility. For purposes of calculating the total impact of this alternative, the other INTEC HLW facilities addressed in this appendix are assumed to be closed under the Performance-Based Closure Alternative.

- Disposal of Class C Grout in a Low-Activity Waste Disposal Facility – The Class C grout produced under the Transuranic Separations Option under the Separations Alternative would be placed in a low-activity waste disposal facility. For purposes of calculating the total impact of this alternative, the other INTEC HLW facilities addressed in this appendix are assumed to be closed under the Performance-Based Closure Alternative.

C.9.2 SCENARIOS AND ASSUMPTIONS

Because analyzing the potential impacts requires projection of events that would occur in the future, DOE developed scenarios and assumptions to provide a quantitative basis for evaluating the impacts. DOE believes it has used reasonable judgment to develop scenarios that will allow a meaningful comparison of the impacts among alternatives rather than attempting to calculate an upper bound for the impacts through the use of overly conservative assumptions.

The major assumptions that DOE made in its assessment of impacts are as follows:

- The land in question is the general vicinity of the current INTEC. Institutional control would be maintained over this area until the year 2095. After that time, it is assumed for purposes of analysis that the land would not be controlled, and might be used for residential, industrial, or recreational purposes for a period of roughly 10,000 years.

- For alternatives other than the No Action and Clean Closure alternatives, DOE assumed that a grout material would be used to fill the Tank Farm and bin sets to provide long-term structural stability. DOE also assumed that this grout would be specially engineered to provide favorable characteristics that would inhibit the leaching of some contaminants to the aquifer. For purposes of analysis, DOE assumed that the grout would be similar to that used in high-level waste tank closure activities at the Savannah River Site.

- Future human receptors who use or work on this land may be exposed to radionuclides, or to carcinogenic or non-carcinogenic contaminants. As a result of the screening assessment described in Section C.9.3.6, intakes from the groundwater pathway were assessed in detail for the following contaminants of potential concern:

  – The long-lived radionuclides technetium-99 (Tc-99) and iodine-129 (I-129)

  – Cadmium, a chemical contaminant which is associated with both cancer and noncancer health effects

  – Fluorides and nitrates, which are non-carcinogenic toxic substances.

- Exposure to direct radiation from radionuclides in closed facilities was assessed using estimated radionuclide inventories. The reference inventory for each facility applies to the year 2016; these were decay-corrected to apply to the time frame of the specific cases assessed.

- Except for the case of No Action for the bin sets, there would be no credible scenario under which significant amounts of radionuclides from closed facilities would be released to air.

- Surface water exposure scenarios were not considered credible events for the setting and time frames analyzed.

- All residual contaminants would reside on the floor of the tanks or facilities. For those alternatives that use Class A and Class C grout, the contaminants in the grout would be uniformly distributed throughout the grout instead of being deposited on the floor. However, to be conservative, the residual facility contaminants would still be assumed to reside on the floor.

- At 500 years, the concrete and grout in the tanks and facilities assumes the same hydrogeologic transport characteristics as the surrounding soil; however, chemical properties of grout and concrete would remain unchanged. This assumption is consistent with the NRC draft position that no credit can be taken for engineered physical components after at most 500 years (NRC 1994). In addition, the design life of the bin sets is estimated to be 500 years.

- The present environmental conditions in and around the dispositioned facilities (i.e., meteorology, infiltration rates, geologic conditions) would remain constant throughout the entire 10,000-year period of analysis.

- The analytical endpoints of the assessment were as follows:

  - Radiation (radionuclide intake and direct radiation exposure) – Total effective dose equivalent and lifetime excess total cancer risk
  - Cadmium – Intake rate (mg/kg-d), associated cancer risk (chance per million), and hazard quotient, which is the ratio of the chronic intake rate to the reference dose (RfD)
  - Fluorides and nitrates – Intake rate (mg/kg-d) and hazard quotient

- Risk assessment results are presented and discussed primarily for purposes of comparison between closure scenarios, and do not include results of baseline risk assessments performed for other INTEC sources.

Assumptions related to specific alternatives are described in the following sections.

No Action Alternative

As discussed in Chapter 3, under the No-Action waste processing alternative, waste would remain in the Tank Farm and bin sets. Therefore, in this appendix, DOE has evaluated the potential long-term consequences of failure of the Tank Farm and bin sets that contain this material. In its evaluation of impacts, DOE has assumed that no fill material is placed in the facilities. Section C.9.3.1 describes DOE's assumptions on the source material.

Clean Closure

As described above, this alternative would involve removing all residual contaminants so as to be indistinguishable from background. Because there would be no source term to evaluate over the period of analysis, long-term modeling for this alternative was not performed.

Performance-Based Closure

Under this alternative, the facilities would be cleaned to meet performance-based objectives. Following cleaning, the facilities would be closed. For the Tank Farm and bin sets, a clean grout material would be used to fill the volume of these facilities. As discussed above, DOE assumed, for purposes of analysis, that the grout to be used would be similar in composition and properties as that used for high-level waste tank closure activities at the Savannah River Site (DOE 1997). Although studies have shown that cementitious materials (such as grout or concrete) can be expected to last for extended periods of time approaching 1000 years or more (Poe 1998), DOE assumed that the grout and concrete structure of the bin sets and tanks will fail structurally at 500 years post-closure. The grout was assumed to completely cover the contaminants, which were assumed to reside on the floor of the facilities.

The major mechanism for contaminant transport in these facilities would be leaching by water. Because the facilities are above the aquifers underlying INTEC, the primary source of water for leaching would be precipitation that moves vertically through the facilities and transports contaminants to the aquifer system. Precipitation in the region of INTEC averages approximately 9 inches per year. However, due to evaporation and runoff, the actual infiltration rate into soils in this area is about 1.6 inches per year (Rodriguez et al. 1997).

During the 500 years prior to structural failure of the facilities, a minimal amount of leaching was assumed to occur, and DOE took no credit for the presence of steel liners in the Tank Farm. The hydraulic conductivity of the grout and the concrete in the facilities would limit the actual amount of water that can move through the facilities. However, after the assumed failure occurs, the cementitious materials were assumed to have a much higher hydraulic conductivity, allowing more water to pass through the facilities and leach contaminants to the aquifer system. The chemical characteristics of the grout, however, are expected to persist long after the analysis period of 10,000 years (DOE 1998). Therefore, DOE believes that the chemical characteristics of the water passing through the grout would continue to inhibit the amount of leaching that would occur after failure. Section C.9.6 discusses the input parameters and assumptions in more detail.

Closure to Landfill Standards

The assumptions for this alternative were identical to those for Performance-Based Closure. As discussed in Section C.9.3, DOE assumed the same inventory of contaminants for this alternative and the Performance-Based Closure Alternative. Therefore, DOE relied on calculations for the Performance-Based Closure Alternative to be representative of impacts for this alternative.

Class A and Class C Grout Disposal

As discussed earlier, a Class A or Class C grout mixture would be generated as a result of the waste processing alternatives described in Chapter 3. DOE assumed for purposes of analysis that this grout would be similar in chemical composition to that described above for the Performance-Based Alternative except that the grout in this alternative would have contaminants in it from implementing the waste processing alternatives.

Performance-Based Closure with Class A or Class C Grout Disposal

This alternative was analyzed in a similar manner as the Performance-Based Closure Alternative, except in this instance, the grout that would be used to fill the Tank Farm and bin sets was assumed to contain additional contaminants beyond that already present in the facilities to be closed. Therefore, there would be two sources of contaminants in the Tank Farm and bin sets: the residual contamination following cleaning activities and the contamination in the grout to be poured into the facilities.

Disposal of Class A or Class C Grout in a Low-Activity Waste Disposal Facility

If DOE selected this alternative, the Class A or Class C Grout would be disposed of in a low-activity waste disposal facility specially constructed to minimize leaching. The other facilities would be closed in accordance with alternatives selected by the decisionmaker. For presentation of impacts, DOE has assumed that the Tank Farm and bin sets would be closed under the Performance-Based Alternative.

Under this alternative, the grout was assumed to remain intact for 500 years, after which time the grout would fail in a similar fashion as that described for the Performance-Based Closure Alternative. The increased hydraulic conductivity would allow more water to flow through the grout, but the chemical properties of the grout were assumed to remain unchanged over the period of analysis.

C.9.3 FACILITY CONTAMINANT SOURCE TERMS

This section describes the methodology and assumptions used by DOE to estimate the amount of material remaining in INTEC HLW facilities after closure for each of the facility disposition alternatives described in Section C.9.2. The amount of contaminants within the waste affects the quantity that could ultimately be transferred to the aquifer. Larger initial amounts would generally lead to greater fluxes to the aquifer while lower initial amounts would cause lower fluxes and hence lower concentrations of contaminants in the aquifer. The exception to this occurs for contaminants that are limited by their solubility in solution. Plutonium is an example of such a contaminant in that the initial amount in the source layer may far exceed the ability of the interstitial solution to dissolve the plutonium. In this case, a higher initial amount would not necessarily cause a greater flux to the aquifer, but the transfer to the aquifer would be protracted due to plutonium's limited solubility.

DOE performed engineering studies to estimate the amount of contaminants that could be left in facilities following disposition. Table C.9-1 lists these values by facility and alternative. As discussed in Section C.9.2, for purposes of analysis, DOE assumed that the amount and character of the residual inventory would be the same for both Performance-Based Closure and Closure to Landfill Standards (for those facilities for which both facility disposition alternatives are applicable).

For all pathways except external irradiation, the source inventories in Table C.9-1 were used because the entire inventories were available for transport to the receptor location. The values in Table C.9-1 for radionuclides have been decayed to the year 2016 to provide a consistent basis for analysis. For external irradiation, however, DOE postulated that the receptor would be closer to a particular facility than the others. Consequently, the receptor would not be exposed to all the contaminants in all the facilities to the same degree.

C.9.3.1 No Action Alternative

Tank Farm

DOE developed Tank Farm inventory and source terms for the No Action Alternative (Beck 1999b) using the following assumptions:

- The New Waste Calcining Facility calciner would operate until June 2000 then would be closed

- The High-Level Liquid Waste Evaporator would operate from September 2000 until all the dilute waste is concentrated and the pillar and panel vaulted tanks are empty in FY-2003

- Cease use of pillar and panel tank would be achieved by June 30, 2003
- Five tanks would remain in service to be filled by future waste generation
- Tanks WM-180, WM-188, & WM-189 would be at capacity in FY-2003
- Tank WM-187 and WM-181 would continue to receive waste until full
- Tank WM-190 would remain as the spare tank
- Newly generated liquid wastes would have a typical SBW composition when added to the Tank Farm

Based on the assumptions, DOE estimated the contents of each of the five 300,000-gallon storage tanks and the eventual date they would be filled. The estimated tank volumes are listed in Table C.9-2. These results were then used to generate an estimated source term. The source terms are described in Beck (1999c) and are listed in Table C.9-1.

Table C.9-2. Estimated Tank Farm volumes under the No Action Alternative[a].

Tank	Volume (gallons)
WM-180	262,000
WM-187	285,000
WM-188	285,000
WM-189	285,000
WM-181	285,000
Total	1,402,000

a. Source. Beck (1999b).

Bin Sets

Since December 1963, fluid-bed calcining has been employed at INTEC to convert aqueous wastes to granular solids. The wastes are processed in a heated fluidized-bed calciner where they undergo thermal decomposition to metallic oxides or fluorides, water vapor, and nitrogen oxides. The solids are transported to stainless steel bins for interim storage. A summary of the volumes of liquid wastes calcined over the years is presented in Table C.9-3. Detailed operational chronologies for the various calcination campaigns are presented by Staiger (1999).

The characteristics of the calcine in the bin sets are described in detail by Staiger (1999). An accurate quantitative inventory of the solids stored in the bin sets is not available. Staiger (1999) presents the

Table C.9-3. Summary of calcination campaigns[a].

Campaign	Date	Liquid to Calciner (gal)	Solids Stored (m^3)
WCF 1	Nov. 1963 – Oct. 1964	512,000	217
WCF 2	March 1966 – March 1968	989,000	422
WCF 3	Aug 1968 – Jun 1969	329,000	170
WCF 4	May 1970 – Jan 1971	225,000	139
WCF 5	Sep 1971 – Apr 1972	300,000	164
WCF 6	May 1973 – May 1974	386,000	196
WCF 7	May 1975 – Jan 1977	375,000	257
WCF 8	Sep 1977 – Sep 1978	469,500	256
WCF 9	Jun 1979 – Mar 1981	476,000	327
NWCF 1	Aug 1982 – Jun 1984	1,553,000	813
NWCF 2	Sep 1987 – Dec 1988	797,800	445
NWCF 3	Dec 1990 – Nov 1993	752,500	386
NWCF 4	May 1997 – May 1999[b]	661,300	480

a. Source. Staiger (1999).
b. Through Batch 489 and 252,900 gallons of evaporation by the High-Level Liquid Waste Evaporator.

results of a comprehensive search of many sources of information summarized in the appendices to that report.

Individual bin inventories have been estimated from calciner liquid feed information. Information that is of current interest, particularly the concentration of long-lived radioactive isotopes and RCRA metals, was not routinely collected at the time of waste generation. To fill this information gap for long lived radioactive species, the inventories were estimated based on evaluation of the available information and process knowledge.

Chemical

Chemical information was assembled from original Tank Farm and calciner feed tank sample analysis reports; transcribed analysis information found in reports, letters, and data sheets; as well as knowledge of process; and miscellaneous notes. These data were adjusted to account for dilution and chemical adjustment, where appropriate. Where analytical determinations were not made and the constituent was known to be present, estimates were made of the chemical content. Additives to feed batches were determined from individual feed make up sheets where available and were estimated when sheets were not available.

Total quantities of material in individual bins have been estimated. The filling sequence was estimated using thermocouple measurements. This information was used to determine how the calcine was distributed between the several bins in the storage facility. Chemical amounts are reported in Table C.9-1.

The quantity of mercury in the calcine product was adjusted to reflect observed mercury retention in the calcine product. It was assumed that 70 percent of the mercury was retained in the product for campaigns one, two, and three, which operated at a 400°C fluidizing temperature. During subsequent campaigns, operating at 500°C, a 1.0 percent retention of mercury in the product was assumed. This assumption is supported by the following work:

- Dissolution of calcine resulting from processing of mercury containing feed during New Waste Calcining Facility campaign H-4 showed approximately 50 parts per million mercury present.

- For dilute zirconium feed, only an insignificant fraction (approximately 0.5 percent) of feed stream mercury was present with the fines and this fraction is even less for the calcine product.

- For SBW, 1.7 percent of the mercury was found in the fines when aluminum nitrate was used as a calcination additive and 0.13 percent was found when dilute zirconium feed is the additive. The retention was substantially lower for bed material.

Radiochemical

The concentrations of radionuclides are estimates. Limited definitive information was provided for radionuclides at the time fuel was shipped to INTEC. The estimation methodology predicted fission product inventories using a well known computer code, "ORIGEN2.1, Isotope Generation and Depletion Code Matrix Exponential Method." Resultant radionuclide concentrations in the calcine are presented in Table C.9-1, which was compiled by the following method. First a list of nuclides of interest was generated using Table 1 and Table 2 in 10 CFR 61.55. Those species that are volatile/combustible during calcination, H-3 and C-14, are not expected to be present in the calcine and are not shown. Activated metal species were eliminated because there is no activated metal sorted with the calcine. Measurements have confirmed that only a small fraction of the iodine present in the reprocessed fuel is potentially sent to calcine storage, therefore, I-129 is not included in the list for the calcine storage bins (Staiger 1999).

The nuclide concentration in the various feed streams shown were estimated based on decay to 2016 of the laboratory measured concentration for Cs-137. It was assumed that the cesium is not preferentially concentrated in plant waste and that the ratios in the wastes are the same as those in the parent fuel prior to reprocessing.

C.9.3.2 Performance-Based Closure/Closure to Landfill Standards

Tank Farm

The residual source terms remaining in the Tank Farm after closure (for Performance-Based Closure or Closure to Landfill Standards) were derived based on the following assumptions, which are further described in Beck (1999a).

- Starting tank heel volumes would be per historic heel volume data adjusted as in Table C.9-4.

Table C.9-4. Tank Farm heel volume estimates.[a]

Tank	Historical	Adjusted Estimate	Comments
WM-180	9,500 gal.	10,000 gal.	
WM-181	7,500 gal.	10,000 gal.	
WM-182	3,600 gal.	5,000 gal.	
WM-183	----	5,000 gal.	Never Emptied
WM-184	----	5,000 gal.	Never Emptied
WM-185	4,600 gal.	5,000 gal.	
WM-186	----	5,000 gal.	Never Emptied
WM-187	13,700 gal.	12,000 gal.	Should be lower (instrument calibration)
WM-188	13,700 gal.	12,000 gal.	Should be lower (instrument calibration)
WM-189	5,000 gal.	5,000 gal.	
WM-190	----	5,000 gal.	Never Filled

a. Source. Beck (1999a).

- When a tank is jetted down during flushing (flush water would be removed by using existing jets and not submersible pumps), the diluted liquid would be transferred to another large Tank Farm tank along with any solids that are carried out with the liquid.
- Every heel (before closure flushes) would be assumed to be a SBW heel.
- Tank heels would be flushed to pH=1.5 - 2.0. For the purposes of calculating source terms, pH would be assumed to be 2.0.
- Complete mixing of flush water with heel by using a mixing ball during the wall washing process would be achieved.
- There would be no precipitation due to pH adjustment.

- Solids on walls of tanks would rinse off and would not significantly add to the solids and source term load.

- All of the original mass of tank solids would remain in each tank.

- Vault contamination is insignificant compared to the levels left in the tanks (except for sand under tanks WM-185 & WM-187).

- Each tank has a very limited pedigree with respect to radionuclides in either the liquid or solid wastes. To overcome this deficiency, inventories for typical waste types at INTEC have been prepared. These residual calculations assume that the waste existing in the individual tank heels is represented by SBW. The inventories were calculated by normalizing the calculated inventories to the activity of the Cs-137 (decayed to 2016) measured in the tank.

- Tank solids are estimated to be one inch thick with a porosity of 34 percent. The thickness of the solid layer is a conservative estimate based on the recent video inspections of the inside of tank WM-188. The porosity conforms to the voids observed in loose packed uniform sand. The solids are assumed to be completely removed from the internal surfaces except the tank bottom. It was assumed that the solids radioactivity is derived from a variety of sources and is best represented by the constituents associated with SBW. Again radionuclide distributions were calculated by normalizing to the measured Cs-137 concentration, based on the empirical data from the sampling of tank WM-188. Concentrations of Pu-238, Pu-239, Np-237, and Am-241 were corrected to agree with sample results.

- Interstitial liquid in the heel solids is assumed to be the liquid filling the particular tank after dilution to pH 2.

- Flushing operations would disturb most of the solids on the bottom of the tank thus achieving dilution of the activity trapped in the interstices. However, a 10 percent fraction is assumed to be shielded from agitation and therefore does not experience dilution of the interstitial liquid.

- Interstitial liquid radiochemical concentrations are calculated from Wenzel (1997) normalized to the Cs-137 concentration.

- The heel solids are assumed to be the same for all tanks and have a bulk density of 1.22 g/cm^3. This wet bulk density was corrected to a dry particle density of 1.65 g/cm^3 assuming that the porosity is 34 percent and that the interstices were filled to 30 percent by 1.28 specific gravity solution.

- The tank support sand pads under WM-185 and WM-187 were significantly contaminated with aluminum type waste during siphoning incidents in March 1962. The interstitial volume of the sand pad under tanks WM-185 and WM-187 is calculated at 2100 gallons assuming a porosity factor of 0.34. Infiltration water (from surface water run-off) flushing of the sand pad has occurred since the siphon event. Periodic removal of the infiltrating water is assumed to have flushed some of the activity from the sand. The residual activity for these species is added to their respective tanks.

- The residual liquid heel is jet pumped to 400 gallons at the time of grouting.

Bin Sets

The volume of the solids in the emptied bin set vessels is assumed to be 0.5 percent of the filled volume (Staiger 1998). The concentrations of radiological and chemical constituents in the emptied vessels is assumed to be the same as for the filled bin sets under the No Action Alternative, described above. The residual activity in the bin sets after closure is listed in Table C.9-1.

Other Facilities

Other existing INTEC HLW facilities evaluated in this appendix are the Process Equipment Waste Evaporator (CPP-604) and the New Waste Calcining Facility (CPP-659). DOE assumed (Beck 1998) that the residual inventory in these facilities after closure would be less than the amount remaining in the Waste Calcining Facility (CPP-633) after it was closed. DOE conservatively assumed that the residual inventory in the Process Equipment Waste Evaporator and New Waste Calcining Facility would be equal to the Waste Calcining Facility. The characteristics of the residual remaining in the Waste Calcining Facility are described by Demmer and Archibald (1995). The residual activity in the Process Equipment Waste Evaporator and New Waste Calcining Facility after closure is listed in Table C.9-1.

C.9.3.3 Class A or Class C Grout Disposal in a New INEEL Disposal Facility

As described in Chapter 3, approximately 27,000 cubic meters of Class A grout would be produced under the Full Separations Option and approximately 22,700 cubic meters of Class C grout would be produced under the Transuranic Separations Option. One method evaluated for disposal of this grout is disposal in a new Low-Activity Waste Disposal Facility, an engineered near-surface disposal facility. The characteristics of the radioactive and chemical constituents in this Class A or Class C grout are described by Russell et al. (1998) and are listed in Table C.9-1.

C.9.3.4 Performance-Based Closure with Class A or Class C Grout Disposal

In addition to disposal in a new Low-Activity Waste Disposal Facility, as described in Section C.9.3.3, DOE evaluated a second onsite method for disposal of the Class A or Class C grout produced under the Full Separations and Transuranic Separations Options. This second onsite disposal method is disposal in the Tank Farm and bin sets, after these facilities have undergone performance-based closure. The Class A or Class C grout would serve to bind residual contaminants remaining in these facilities and provide structural stability in the closed facilities.

DOE assumed that the Class A or Class C grout would be divided equally between the Tank Farm and bin sets (i.e., one-half of the volume in each facility). The Class A or Class C grout would be in addition to the residual contamination remaining in the Tank Farm and bin sets after performance-based closure (as discussed in Section C.9.3.2). Table C.9-1 lists the characteristics of the radioactive and chemical constituents in Tank Farm and bin sets under the Performance-Based Closure with Class A Grout Disposal and the Performance-Based Closure with Class C Grout Disposal alternatives.

C.9.3.5 Direct Radiation Exposure

The assessment of exposure scenarios includes cases where future receptors are exposed to direct radiation from either (a) radionuclides in contaminated soil; (b) residual radioactivity in closed facilities including the Tank Farm, bin sets, and other INTEC facilities used for high-level waste management; or (c) facilities that could be used for radioactive waste disposal, including the Tank Farm, bin sets, or a new Low-Activity Waste Disposal Facility. External dose factors were developed for soil and closed facilities using the IDF code, which is part of the GENII package (Napier et al. 1988). DOE developed exposure scenarios for soil and closed facilities for the same categories of receptors as described previously. These scenarios and the associated data and assumptions are described below. Separate sections are provided for closed facility and soil contamination assessments since there are major differences in the methodology between the two. A section is also provided to explain the manner in which dose results from individual cases are summed to arrive at total external dose.

Dispositioned Facilities

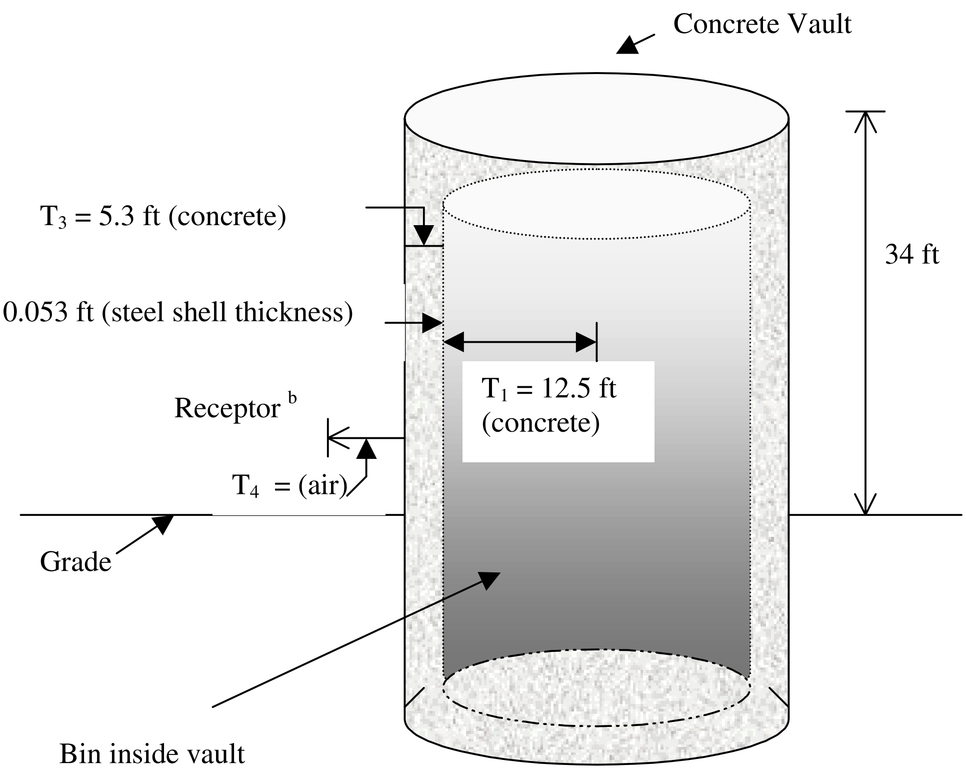
The approach for modeling external dose from radionuclides in dispositioned (closed) facilities began with the development of a conceptual model which defines the source geometry, dimensions, and shielding materials for each source facility. For some existing facilities, this model is closely patterned after the actual construction of the facility under evaluation, while for others simplifying assumptions were necessary. For example, the source geometry and construction materials used for the Tank Farm model closely approximate those of existing storage tanks, whereas a simplified geometry is used to approximate the more complex array of calcine storage bins within a bin set. DOE then made conservative estimates for the average distance between receptor and source for each category of receptor and source facility. These conceptual models and source-receptor distances are illustrated in Figures C.9-1 through C.9-4.

The initial source term for each facility is the estimated radionuclide contents decay-corrected to the Year 2016. For the Tank Farm and bin set modeling, the single tank or bin set with the highest inventory was selected as the source facility to be used for the residual contamination and No Action cases. For cases in which the tank or bin sets are filled with Class A or C grout, the dose from both residual activity and radionuclides in the waste materials are included. Table C.9-5 identifies the specific radionuclides and the estimated activity levels used for each source facility. Although other radionuclides are present in these facilities, the radionuclides listed account for more than 99 percent of the external dose rate over the period of evaluation. The 2016 inventory is used as the source term for all exposure scenarios that occur during the period of institutional control (specifically, the INEEL worker or unauthorized intruder exposure scenarios). For all other scenarios, the radionuclide inventory is decay-corrected to 2095, which is assumed to be the earliest date at which institutional control could be lost.

The next step involved using the IDF model to generate external dose factors (millirem per hour per Ci or millirem per hour per Ci/m^3). The dose factor was then multiplied by the appropriate inventory values (Ci or Ci/m^3) to obtain a dose rate in millirem per hour, which was in turn multiplied by the receptor exposure time (Section C.9.6.4, Table C.9-9) to obtain external dose in millirem.

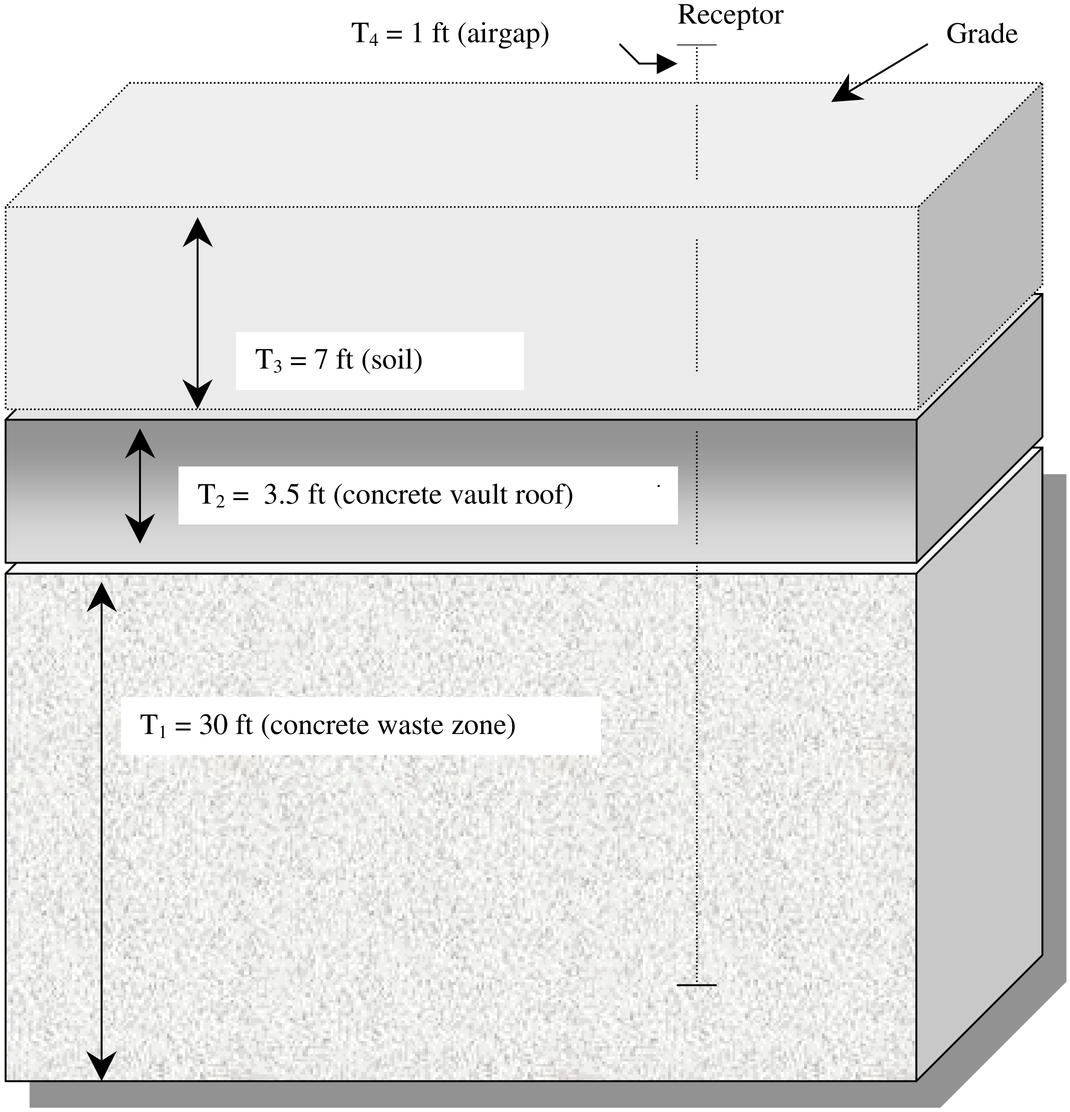
Soil

External dose is also calculated for receptors located over ground that has become contaminated from irrigation with contaminated groundwater. DOE performed these evaluations only for the radionuclides that were quantitatively assessed for the groundwater pathway, namely Tc-99 and I-129 (see Section C.9.3.6). In these evaluations, the Tc-99 and I-129 soil concentration is calculated using the



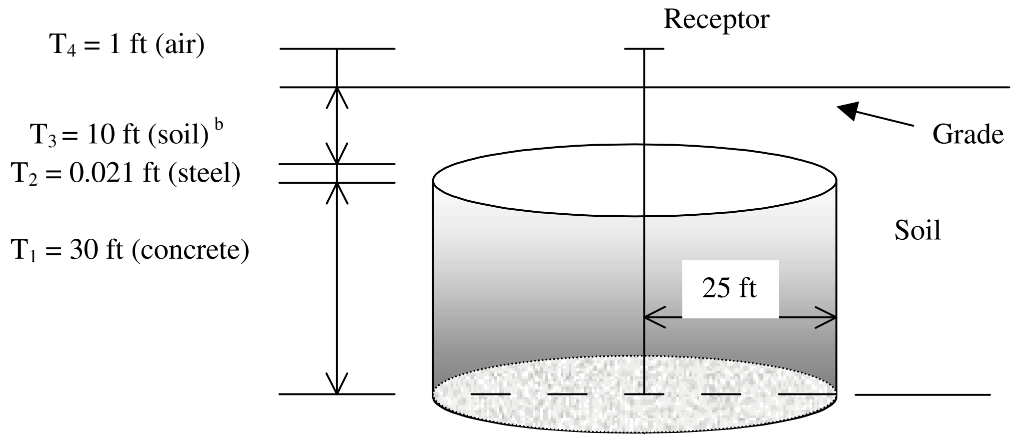
a. Figure not to scale.
b. Distance (air gap) is 3 ft for intruder and 10 ft for other receptors.

Figure C.9-1. Model of bin set with either residual activity or Class A or C grout fill.[a]



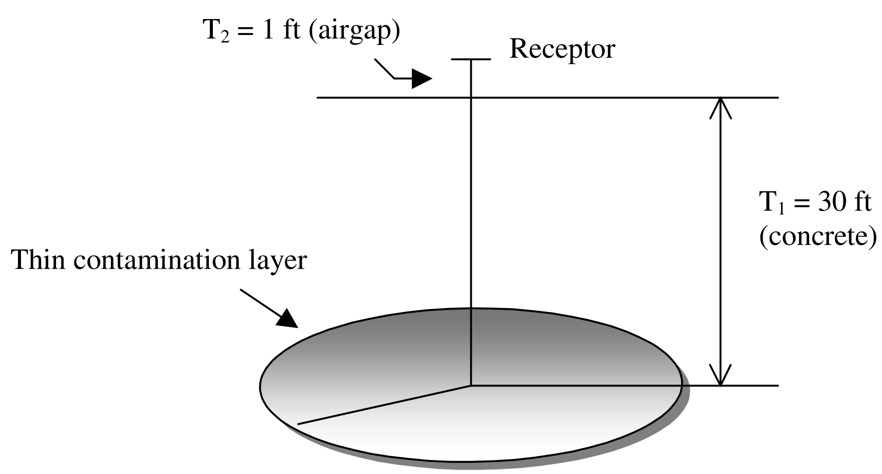
a. Figure not to scale.

Figure C.9-2. Model of low-activity waste disposal facility.[a]



a. Figure not to scale.
b. Not present for intruder scenarios.

Figure C.9-3. Model of Tank Farm storage tank with either residual activity or Class A or C grout fill.[a]



a. Figure not to scale.

Figure C.9-4. Model of New Waste Calcining Facility and Process Equipment Waste Evaporator.[a]

following equations, which are the same as those employed for the groundwater-soil-food product ingestion pathway:

$$C_s(t) = \frac{\frac{\dot{I}_v \cdot CF}{L_i}\left(t_e + \frac{e^{-(L_i + t_e)}}{L_i}\right) + \frac{C_{so}}{L_i}\left(1 - e^{-(L_i \cdot t_e)}\right) - \frac{\dot{I}_v \cdot CF}{L_i^2}}{t_e}$$

where:

$C_s(t)$ = average concentration of radionuclide in soil for the exposure period t_e (mg/kg)
t_e = exposure period (30 y = 10,950 d)
$\dot{I}_v$ = radionuclide input rate from irrigation (mg/g-d)
L_i = leach rate constant (d^{-1})
C_{so} = concentration of radionuclide in soil at the start of the residential exposure period (assumed to be 0 mg/kg)
CF = conversion factor for grams per kilogram (1,000 g/kg)

The radionuclide input rate is estimated by:

$$\dot{I}_v = C_w \frac{I_R}{\rho T}$$

where:

$\dot{I}_v$ = contaminant of potential concern input rate from irrigation (mg/g-d or pCi/g-d)
C_w = average concentration of contaminant of potential concern in groundwater during the exposure period (mg/liter or pCi/liter)

I_R = irrigation rate $\left[2.09 \frac{liter}{m^2 \cdot d} = \frac{8.47 \frac{liter}{m^2 \cdot d} \cdot 90d}{365d}\right]$
ρ = soil density (1.5 x 10^6 g/m^3)
T = thickness of root zone (0.2 m).

The leach rate constant (L_i) was estimated as:

$$L_i = \frac{P \cdot CF}{\theta_c \left(1 + \frac{K_d \rho}{\theta_c}\right) T}$$

where:

L_i	=	leach rate constant (d^{-1})
P	=	net water percolation rate (0.86 m/y), which includes contribution from precipitation (0.1 m/y) and irrigation (0.76 m/y)
θ_c	=	volumetric water constant in source volume (0.41 m^3/m^3)
K_d	=	contaminant of potential specific soil-to-water partition coefficient (cm^3/g)
ρ	=	soil density (1.5 g/cm^3)
T	=	thickness of root zone (0.2 m)
CF	=	conversion factor for years per day (0.00274 y/d).

For external dose modeling, the radionuclides of concern are assumed to be evenly distributed in a 15 cm-thick source layer which is modeled as an infinite slab. (This is the default method in GENII for evaluating external dose from soil contamination.) The dose rate is evaluated at a point 1 foot above the slab, and is converted to dose by multiplying by the exposure time that applies to each receptor category.

<u>Summation of External Doses</u>

The final process in the external dose assessment involves the adding of doses from various individual sources to estimate total dose. There are two stages to this process. The first involves adding external doses from each source facility. This assumes that the receptor in question is simultaneously exposed to each source facility that exists under a given exposure scenario at the maximum calculated exposure rate. For example, a receptor that is exposed under the scenario for Class A or Class C grout disposal in the Tank Farm and bin sets is assumed to be simultaneous exposed to the following:

- A Tank Farm storage tank (residual activity plus Class A or Class C grout)
- A bin set (residual activity plus Class A or Class C grout)
- Other dispositioned facilities (New Waste Calcining Facility, Process Equipment Waste Evaporator)

This summation is conservative since a receptor cannot be located in more than one maximum dose location at the same time. However, the cumulative external dose does not include dose from simultaneous exposure to multiple storage tanks or bin sets.

The second stage involves adding the maximum external doses from dispositioned facilities to those calculated for contaminated soil. This summation is also conservative since these maximum doses would occur over different time frames. For example, the dispositioned facility dose rate applies to the Year 2095, while the I-129 and Tc-99 contaminated soil dose rates apply about 1,000 and 10,000 years later, respectively. The source term for the dispositioned facility dose includes all the radionuclides listed in

Table C.9-5, while the contaminated soil source term includes only I-129 or Tc-99. Therefore, the result is not given a specific time.

C.9.3.6 Groundwater Pathway Screening

Unlike the external radiation dose discussed above, the impacts attributable to contaminant transport through groundwater do include the contributions from all tanks and bins. The original list of contaminants present in HLW facilities to be closed included a very long list of radiological and chemical constituents. For example, the initial Tank Farm inventory data included 143 radionuclides and 20 chemical constituents (plus numerous other chemicals present in only trace amounts). Therefore, DOE developed and applied a method (referred to here as "screening") to identify those contaminants of potential concern (COPC) that warrant detailed quantitative analysis. The screening method that was applied to the Tank Farm and bin sets closure scenarios is described below.

Radionuclide Screening

An illustration of the general process used for radionuclide screening is presented in Figure C.9-5. The screening for both the Tank Farm and bin sets started with total decay-corrected residual inventory for the Year 2016. The "first cut" involved all radionuclides that either (a) had a half-life that was less than 10 years, or (b) were present in very low amounts. For the latter, a nominal value of one-billionth (1×10^{-9}) of the total activity was used as a cutoff. The short half-life criterion was used since for even the most mobile species the migration time through the tank or bin structures (tanks, vaults, etc.) and the underlying vadose (unsaturated) zone to the aquifer is expected to be on the order of hundreds of years (i.e., concrete and grout in the tanks and facilities are assumed to maintain their integrity for 500 years).

The next step was to apply a radionuclide-specific "ground burial screening factor" from NCRP Report No. 123, *Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground* (NCRP 1996). This screening factor is ideally suited for this purpose, in that it considers a range of factors, including half-life, migration time, and potential dose to receptors by inhalation, ingestion and external exposure modes. This screening step was performed by multiplying the amount of each radionuclide remaining in the inventory by the screening factor. The radionuclides were then ranked by this product and the products were summed. Radionuclides whose product was greater than a nominal one-millionth of the sum were considered candidates for further evaluation. The radionuclides surviving these initial screens are identified in Table C.9-6.

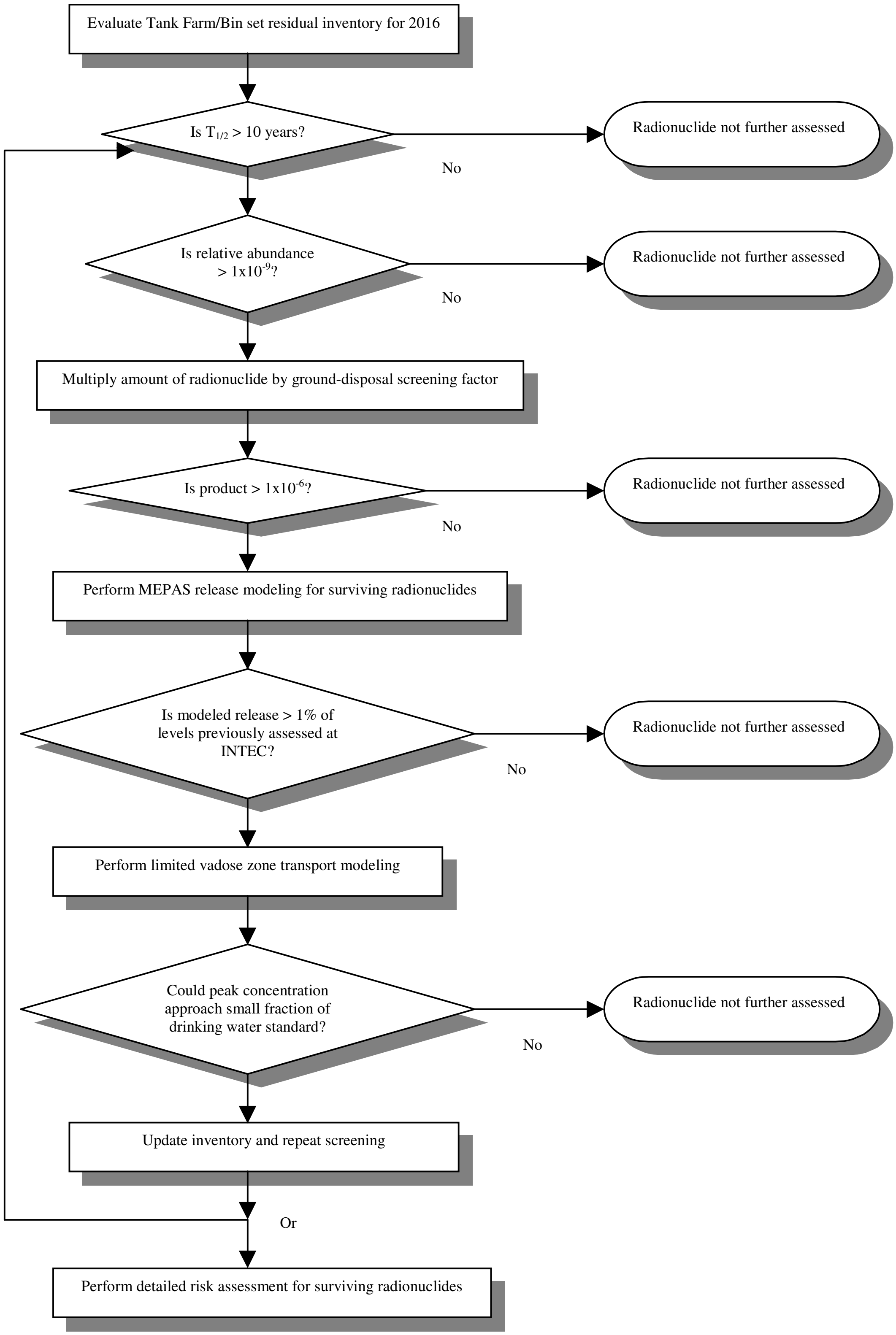


Figure C.9-5. General process used for radionuclide screening for groundwater pathway assessment.

DOE then performed release modeling using the MEPAS code (Buck et al. 1995) and compared the results to those of other modeling evaluations previously performed for INTEC activities. Specifically, in order for the radionuclide to be further evaluated, the estimated total activity released to the vadose zone under any closure scenario (including landfill scenarios) must be greater than 1 percent of the release evaluated for that same radionuclide in the INTEC baseline risk assessment (Rodriguez et al. 1997). That study established the health risk to future human receptors for releases which are generally much larger than those projected under the facility disposition alternatives. This enabled DOE to apply this comparison step to screen out those radionuclides that previous analysis has clearly shown will not pose a risk via the groundwater pathway at the projected level of release.

Finally, DOE performed limited transport modeling to indicate whether any of the surviving radionuclides could be eliminated based on (a) travel time to the aquifer, or (b) very low aquifer concentrations compared to drinking water standards. Cs-137 and Sr-90 were eliminated from further consideration on these bases. DOE estimated the travel time for Cs-137 at about 9,800 years. With a half-life of only 30 years, virtually all of the Cs-137 would have decayed after such a long duration. Sr-90, which has a half-life of about 28 years, requires much less transport time to reach the aquifer; however, the activity would still decay to levels such that the peak estimated concentration at the vadose zone-aquifer interface (5.4×10^{-14} pCi/l) would be an exceedingly small fraction of the drinking water standard (8 pCi/l).

As a result of this process, DOE selected two radionuclides for detailed quantitative analysis: Tc-99 and I-129. The dose and heath risk impacts associated with these long-lived radionuclides were then quantitatively assessed for all facility disposition alternatives scenarios (not just those which met the 1 percent release criterion).

After the initial screening was performed, DOE revised the residual radionuclide inventory estimates for the Tank Farm and bin sets and developed initial inventory estimates for the No Action alternative. DOE also revised the estimates for radionuclide releases from the Tank Farm and bin sets under the performance-based closure or closure to landfill standards alternatives, as well as under the No Action closure alternative for these facilities. Following these updates, the screening process was repeated and DOE confirmed that none of the radionuclides previously screened out would qualify for further analysis based on revised inventory and release rate estimates.

Nonradiological Contaminant Screening

The approach used in identifying chemical COPCs warranting further analysis was based primarily on inventory estimates, toxicity, and results of previous evaluations.

The first step was to identify all chemicals that are both (a) potentially toxic or carcinogenic, and (b) present in the inventory in greater than trace quantities. For the latter, a nominal value of 1 kilogram was used as a threshold. (There is no particular significance to this value; it was used simply as a rough indicator of relative hazard potential). Only two carcinogens – cadmium and nickel – and several noncarcinogenic toxic chemicals met these criteria.

Next, DOE developed a screening parameter based on inventory and potential toxicity. The screening parameter is the inverse of the product of the inventory and the oral reference dose (RfD), which was obtained from the Environmental Protection Agency's *Integrated Risk Information System* (IRIS) database (EPA 1998). If an oral RfD was not available, the contaminant was not selected for further evaluation since ingestion is by far the most important exposure mode for the groundwater pathway. Additionally, if an RfD was not available for a specific compound, the available value for a closely related compound was used (e.g., the RfD for nitrate was used for KNO_3 and $NaNO_3$). The screening products were then summed and chemicals that accounted for 1 percent or more of the total were considered for further evaluation.

For the Tank Farm, mercury and cadmium account for about 98 percent of the screening product sum, while nitrate and fluoride collectively amount to about 1.5 percent of the total. For the bin sets, the majority of the contribution is again from mercury and cadmium (77 percent), while fluoride contributes about 21 percent and nitrate a much lesser amount. Nickel constituted a very small fraction of this total (0.05 percent for the bin sets and 0.02 percent for the Tank Farm) and was therefore eliminated from further evaluation. These four species–cadmium, mercury, fluoride and nitrate–were selected for further evaluation. For both the Tank Farm and bin sets, the combined dose for these four species would be about 99 percent of the total dose.

The final screening step was the same as that used in radionuclide screening, namely, a comparison of release rates to those previously analyzed in the baseline risk assessment. This final step eliminated mercury from further evaluation, as the maximum projected release rate under facilities disposition is only a very small fraction of the release rate previously assessed. The results of the nonradiological screening are presented in Table C.9-7.

C.9.4 CONCEPTUAL AND CALCULATIONAL MODELS FOR ANALYSIS OF IMPACTS

DOE has identified three general mechanisms by which individuals could be impacted by residual contamination as follows:

- Contaminants could be transported to the aquifer under the facilities and moved to a location where humans could remove the contaminated water (through wells) that could be used for drinking, irrigation, and other purposes.

- Contaminants could be released to the environment through airborne pathways due to weathering of the bin sets under the No Action Alternative.

- Contaminants in closed facilities could emit gamma radiation which would irradiate humans in the vicinity.

The following sections discuss the conceptual model used in assessing impacts that arise from these pathways.

C.9.4.1 Groundwater Pathways

Figure C.9-6 illustrates the conceptual model used by DOE in evaluating the impacts to individuals following facility closure. As shown in the figure, the movement of contaminants down to the aquifer would be accomplished via infiltration of rainwater, which leaches contaminants from the residual radioactivity in the facilities and transports it down through the unsaturated zone to the aquifer.

The physical and hydrogeologic setting of INTEC is highly complex, consisting of layered basalt and sediment units. Perched water zones exist within the vadose zone and several large water sources at the surface contribute to them. Chapter 4 describes the hydrogeology in and around the INTEC areas, and that discussion will not be repeated here.

To calculate the impacts to groundwater, DOE used two computer codes. The domains over which these codes were used are illustrated in Figure C.9-6. The leaching of contaminants out of the facilities to the unsaturated zone would be primarily one-dimensional movement in the downward direction; therefore, DOE used the MEPAS (Buck et al. 1995) code developed at Pacific Northwest National Laboratories (PNNL) to calculate the flux of contaminants from the facilities. DOE used TETRAD, an INTEC-specific groundwater model, to calculate the groundwater concentrations after release from the facilities.

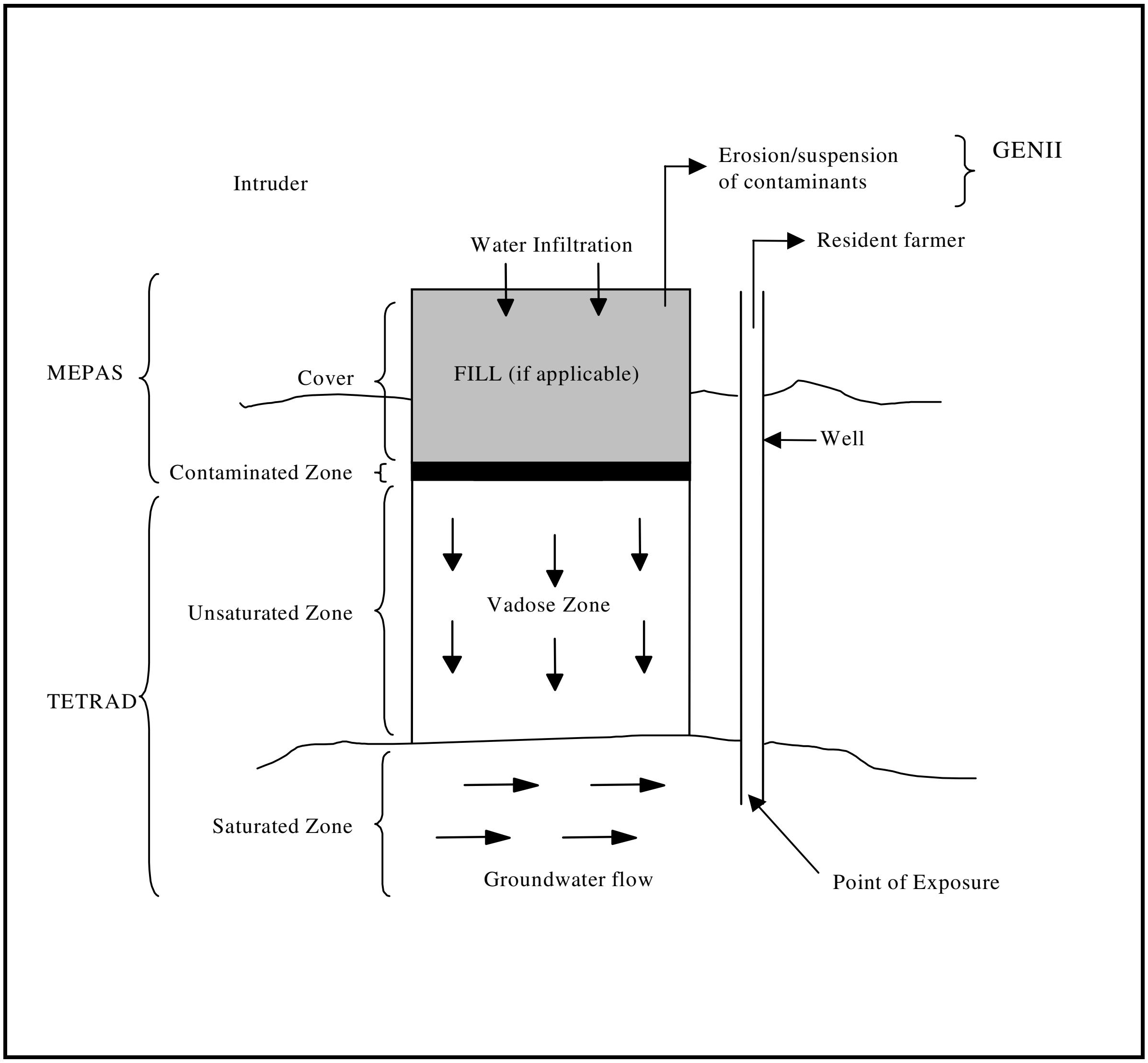


Figure C.9-6. Conceptual site model for facility closure modeling and model domains.

The calculational methodology for MEPAS was developed by PNNL in the 1980s and is based on active transport in one dimension with dispersion allowed in three dimensions. MEPAS uses analytical solutions incorporating partitioning coefficients expressed as K_d values, the porosity and hydraulic conductivity of the media, the water infiltration rate, and a dispersivity coefficient to calculate the amount of leaching that occurs in the source zone and ultimately the flux from the facility. Due to the one-dimensional nature of MEPAS, the solutions are based on the assumption that precipitation will move through the residual contaminants based on the infiltration rate and hydraulic conductivity of the intervening layers between the surface and the residual contaminants, leach material as determined by the partitioning coefficient, and move the contaminants downward to the aquifer. Because MEPAS was used only for flux calculations from the facilities, the groundwater modeling portions of this code were not used, and the flux results were coupled with results from TETRAD to determine the groundwater concentrations.

DOE calculated the fluxes assuming that the facilities would remain intact until structural failure occurs at 500 years post-closure. Therefore, the flux from the facilities is expected to leach only a small amount of contaminants prior to the assumed failure time, after which the structural failure increases the water flow through the facilities and provides greater volumes of leachate to the underlying aquifer.

TETRAD is a three-dimensional model that incorporates site-specific features of the local area, such as transient fluctuations and spatial fluctuations in transport velocities, lithology, and water sources. In addition to infiltration by precipitation, TETRAD can account for other water ingress into the aquifer due to irrigation, the Big Lost River, and other water sources. Therefore, TETRAD was the code of choice for groundwater simulation in the areas around the INTEC.

For modeling purposes, the contaminant sources were defined and incorporated into the simulation model at a grid block or a set of grid blocks, similar to the methodology used during the Waste Area Group-3 Remedial Investigation/Feasibility Study at INEEL (Rodriguez et al. 1997). In the numerical simulation model, the horizontal grid block locations for all sources were defined by overlaying the numerical grid on a map of the INTEC area. Each contaminant source was identified by a grid block and source input parameters were applied for the corresponding block. The simulation model was then used to calculate the transport of contaminants through the vadose zone and to compute a mass flux curve. The cumulative mass flux to the aquifer was then used as input to simulate transport of contaminants in the aquifer and to estimate the resulting groundwater concentrations.

For analysis in this EIS, the results from an extensive TETRAD calculation (Schafer 1999) were used as a scaling tool which could be applied to the flux results from MEPAS to determine the groundwater concentration. DOE adopted this approach to have maximum flexibility in calculating concentrations in the groundwater as estimates of the contaminant inventory in the facilities were refined.

After the groundwater concentrations were calculated, DOE evaluated the impacts from pathways that depend on groundwater as follows:

- Drinking contaminated groundwater
- Using groundwater to irrigate food crops and to water animals used for food
- Inadvertent ingestion of soil contaminated by groundwater irrigation

- Breathing air containing contaminated soil particles
- Absorption through skin contact with contaminated soil or water

The method used for estimating intakes of contaminants from ingestion of contaminated groundwater or crops grown on contaminated site soils or irrigated with groundwater is based on the methodology developed for baseline risk assessments previously performed for INTEC (DOE 1994). DOE evaluated these exposure routes by assuming that the contaminants in soil and groundwater (irrigation water) are transferred to various food crops by means of deposition (from overhead irrigation) and root uptake. The soil concentrations used for root uptake (as well as inadvertent soil ingestion) were calculated under the assumption that the only significant pathway for soil contamination was through irrigation with contaminated groundwater.

C.9.4.2 Airborne Pathways

In addition to the groundwater pathways, DOE evaluated the potential for long term airborne releases and concluded that the only scenario in which such a release is credible involves degradation and ultimate failure of one or more bin sets. The environmental impacts associated with long term failure of one or more bin sets is estimated by assuming that bin set failures become more likely toward the end of the designed performance lifetime of the bin set systems, eventually (after a much longer period of time) becoming a certainty.

In a bounding calculation described in Section 5.2.14, DOE assumed that one bin set could fail shortly after the end of its design life (500 years). Since the likelihood of more than one bin set failing in the same year is remote, this EIS assumes that subsequent failures would occur randomly over the next 1,000 years. Therefore, the bounding calculation conservatively uses the worst case accident scenario involving the bin set with the highest inventory, decayed only to 2095, which is the date DOE has assumed for loss of institutional control.

The bounding event is an air release because calcine released during a failure of a bin set is unlikely to impact the groundwater. Calcine must be dissolved to impact groundwater and would not be mobile as a solid. Dissolution of calcine in an aqueous environment would be very difficult because calcine is only dissolved in a highly acidic solution. No naturally occurring scenario can be envisioned that would result in conditions conducive to dissolution of calcine. Thus, calcine released during a bin set failure would most likely result in an air release.

C.9.4.3 Direct Radiation Exposure

The assessment of exposure scenarios includes cases where future receptors are exposed to direct radiation from either (a) radionuclides in contaminated soil; (b) residual radioactivity in closed facilities; or (c) facilities used for radioactive waste disposal. The latter include the Tank Farm, bin sets, and other facilities that could have a significant inventory of radioactive materials after closure. External dose factors were developed for soil and facilities using the IDF code, which is part of the GENII package (Napier et al. 1988). For contaminated soil, the radionuclides of concern were assumed to be evenly distributed in a 15 cm-thick source layer which is modeled as an infinite slab. The dose is evaluated at a point 1 foot above the slab. For closed facilities, dose rate factors were determined using geometry and shielding thicknesses which approximated the system under evaluation.

C.9.5 RECEPTOR IDENTIFICATION

In its consideration of disposition activities, DOE recognized that certain types of receptors are the most likely to be impacted by these activities. To identify the specific receptors for which analyses would be performed, DOE considered real receptors (known individuals and populations) that could be impacted in the present or near-term time frame, as well as hypothetical receptors that could be exposed under bounding conditions at any time throughout the 10,000 year period of analysis. In postulating these receptors, DOE assumed that certain activities, such as construction of residences or industrial complexes, could occur on the land where the dispositioned facilities are located.

Because it is impossible to predict the future use of the land after the period of institutional control, DOE has chosen a spectrum of receptors to identify representative impacts as follows:

- Maximally exposed resident – a resident farmer who lives in a dwelling constructed on the site after the period of institutional control, and who uses the land for subsistence. This receptor would obtain all of his domestic and agricultural water supply from a well drilled into the aquifer, which is assumed to be affected by contaminant releases from compromised or dispositioned facilities. The average exposed resident is assumed to be exposed both during childhood and as an adult.

- Average resident – like the maximally exposed resident, a resident who lives on the site after the period of institutional control. This receptor would be exposed via the same pathways as the maximally exposed resident, but the consumption rates, exposure duration and frequency would be less. The average exposed resident is assumed to be exposed only as an adult.

- INEEL worker – an adult who would have authorized access to the site during the period of institutional control, and who would work in the vicinity of closed facilities on a full-time basis. This receptor was assessed only for external radiation exposure.

- Future industrial worker – an adult who would have authorized access to the site after the period of institutional control but who is considered to be a member of the public for compliance purposes.

- Unauthorized intruder – a person who could gain unauthorized access to the site during the period of institutional control and would be potentially exposed to contaminants. This receptor was assessed only for external radiation exposure.

- Uninformed intruder – a person who could gain access to the site after the period of institutional control and would be potentially exposed to radionuclides in closed facilities. This receptor was assessed for exposure to external radiation sources (with compromised shielding) and media which have been contaminated with radionuclides released to groundwater.

- Recreational user – a person who routinely would visit the affected area after the period of institutional control and use the area for recreational activities, including camping, hiking, and hunting.

C.9.6 INPUT PARAMETERS

The calculations involved in determining the long-term impacts of the facility disposition alternatives require values to be assigned to numerous parameters. Where possible, DOE used values that are consistent with those used in past analyses at the INEEL or other values that are generally accepted in the nuclear industry.

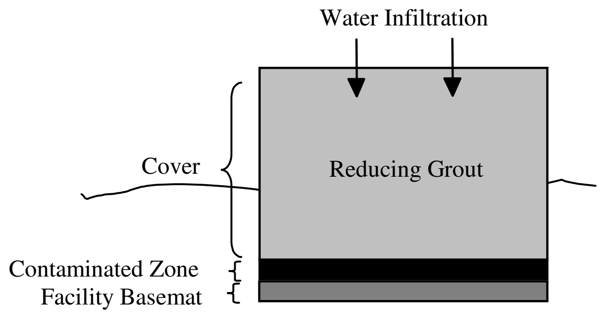
C.9.6.1 Input Parameters Related to Source Term

DOE presented source term information in Section C.9.3 of this appendix and used this information in the evaluation of long-term impacts.

C.9.6.2 Input Parameters Related to Flux Calculations from Facilities

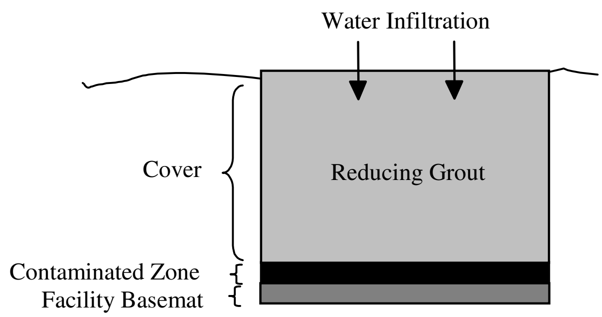
Conceptual diagrams for each of the facility disposition alternatives are provided in Figures C.9-7 through C.9-15. These diagrams indicate the various layers that DOE assumed for purposes of long-term fate and transport modeling. These layers include, where appropriate, (1) the fill material that would be placed on top of the residual contamination, (2) the contaminated zone that contains the residual material remaining after facility closure, and (3) the facility basemat, which is the concrete floor and subfloor portion of the facility below the contaminated zone and above the vadose zone. Table C.9-8 presents the distribution coefficient (K_d) used for each layer in the analysis.

In performing the long-term fate and transport modeling, DOE assumed that each of these layers would have certain properties that would result in differences in parameters such as distribution coefficient (K_d), conductivity, infiltration rate, and porosity. For example, as discussed in Section C.9.1, DOE assumes, for purposes of analysis, that the grout would be formulated specifically to bind contaminants with the grout (i.e., a "reducing" grout). These values assume that the reducing environment designed in the grout would also be present in the contaminated zone. DOE considers this to be a reasonable assumption since the grout layer is very thick compared to the estimated thickness of the source layer such that the pore water that moves from the grout through the source layer would have dissolved the chemical species that would enable a reducing environment to be present in the source layer. DOE further assumes that the



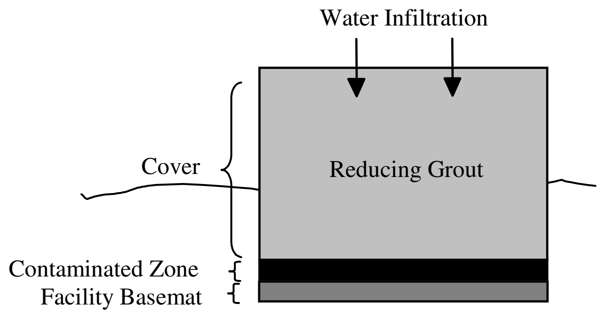
	Fill Material (Reducing Grout)		Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	NA	NA	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38	15	38

Figure C.9-7. Conceptual diagram of facility layers analyzed for the New Waste Calcining Facility and Process Equipment Waste Evaporator



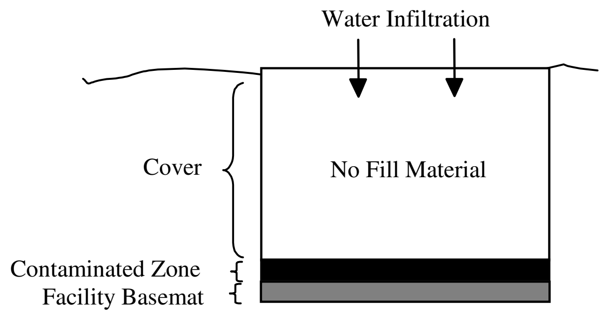
	Fill Material (Reducing Grout)		Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	NA	NA	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38	15	38

Figure C.9-8. Conceptual diagram of facility layers analyzed for the Tank Farm - Performance-Based Closure or Closure to Landfill Standards.



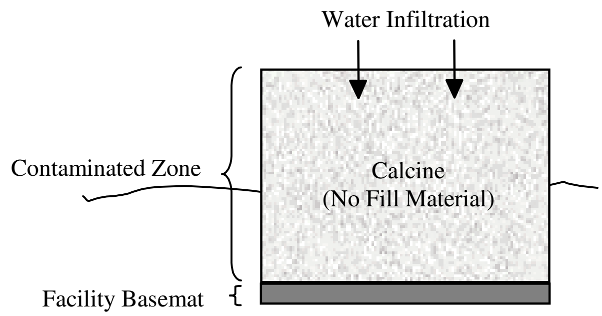
	Fill Material (Reducing Grout)		Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	NA	NA	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38	15	38

Figure C.9-9. Conceptual diagram of facility layers analyzed for the bin sets - Performance-Based Closure or Closure to Landfill Standards.



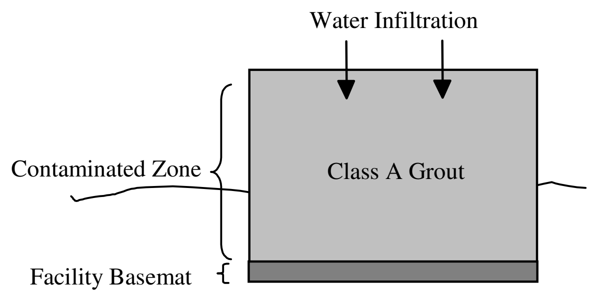
	Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column V	Table C.9-8, Column V	Table C.9-8, Column II	Table C.9-8, Column II
Conductivity (cm/s)	9.6×10^{-9}	9.6×10^{-9}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6
Porosity (%)	15	15	15	38

Figure C.9-10. Conceptual diagram of facility layers analyzed for the Tank Farm – No Action.



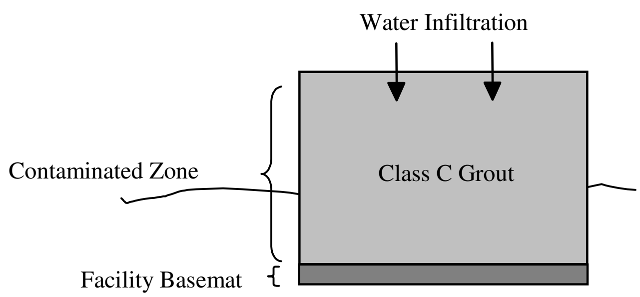
	Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column I	Table C.9-8, Column I	Table C.9-8, Column II	Table C.9-8, Column II
Conductivity (cm/s)	6.6×10^{-3}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6
Porosity (%)	38	38	15	38

Figure C.9-11. Conceptual diagram of facility layers analyzed for the bin sets – No Action.



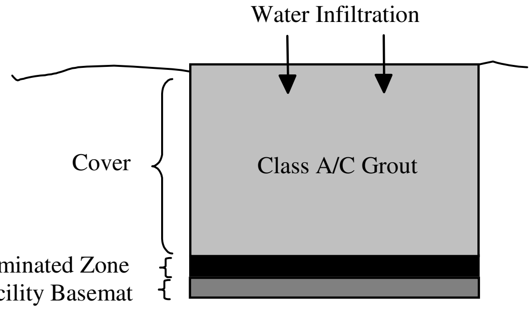
	Contaminated Zone (Class A Grout)		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38

Figure C.9-12. Conceptual diagram of facility layers analyzed for Class A Grout Disposal in New Disposal Facility.



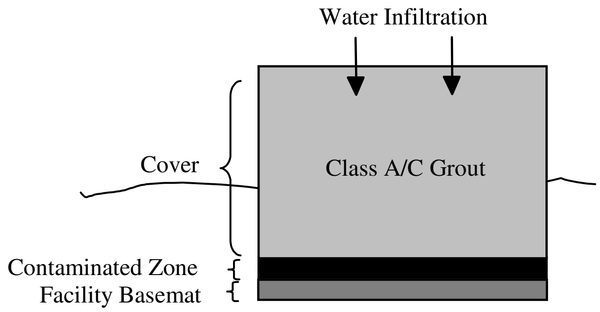
	Contaminated Zone (Class C Grout)		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38

Figure C.9-13. Conceptual diagram of facility layers analyzed for Class C Grout Disposal in New Disposal Facility.



	Fill Material (Class A/C Grout)		Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38	15	38

Figure C.9-14. Conceptual diagram of facility layers analyzed for the Tank Farm – Performance-Based Closure with Class A or Class C Grout Disposal.



	Fill Material (Class A/C Grout)		Contaminated Zone		Facility Basemat	
	0-500 years	500-10,000 years	0-500 years	500-10,000 years	0-500 years	500-10,000 years
K_d (cm^3/g)	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column IV	Table C.9-8, Column III	Table C.9-8, Column III
Conductivity (cm/s)	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}	9.6×10^{-9}	6.6×10^{-3}
Infiltration rate (in/year)	1.6	1.6	1.6	1.6	1.6	1.6
Porosity (%)	15	38	15	38	15	38

Figure C.9-15. Conceptual diagram of facility layers analyzed for the Bin sets – Performance-Based Closure with Class A or Class C Grout Disposal.

chemical characteristics of the grout would persist long after the analysis period of 10,000 years (DOE 1998). Therefore, DOE believes that the grout would continue to inhibit the amount of leaching that would occur after failure. Figures C.9-7 through C.9-15 present the assumed values for the following parameters for each of the layers: distribution coefficient (K_d), conductivity, infiltration rate, and porosity.

As described in Section C.9.2, DOE assumes that at 500 years, the tanks and facilities would undergo complete structural failure and then would assume the same hydrogeologic transport characteristics as the surrounding soil (however, chemical properties of grout and concrete would remain unchanged). Therefore, some of the parameter values associated with each of the facility layers would be different after the assumed failure. Figures C.9-7 through C.9-15 present parameter values for two time periods: 0 – 500 years (before failure), and 500 – 10,000 years (after failure). While Figures C.9-7 through C.9-15 present infiltration rates which are assumed the same as the natural soil rate, infiltration of water is controlled by the low hydraulic conductivity of the facility basemat prior to structural failure.

C.9.6.3 Input Parameters Related to Groundwater Calculations

As discussed earlier, TETRAD was used in the WAG-3 Remedial Investigation/Feasibility Study (Rodriguez et al. 1997), and the same modeling methodology was used in this EIS. Therefore, rather than repeating the parameterizations for that computer model, the reader is referred to the Remedial Investigation/Feasibility Study and the summary report prepared for this EIS (Schafer 1999) for further information.

C.9.6.4 Input Parameters Related to Receptor Impact Calculations

As discussed earlier, DOE calculated impacts to receptors using the methodology embodied in previous baseline risk assessments performed at the INTEC. Understandably, the calculations involve the use of many constants that account for transfer of contaminants to media that serve as intake sources for the postulated receptors and for individual habits of these postulated receptors. These constants may be either generic (as in the case of receptor body weight), or they may be specific to receptors, scenarios or contaminants. Solving the equations is facilitated by the use of summary intake factors, which have been developed for each receptor and exposure mode. These summary intake factors provide a simple but effective means of calculating contaminants of potential concern intake from media concentration. For example, the summary intake factor for intake of radionuclides via groundwater ingestion by the maximally exposed resident has a value of 2.1×10^4 in units of liters. Multiplying this value by the groundwater concentration in picocuries per liter yields the estimated intake of the radionuclide, in picocuries, by this receptor. Tables C.9-9 and C.9-10 show the values of the assumed parameters used in this EIS.

C.9.7 RESULTS OF IMPACT ANALYSIS

This section describes the potential human health risk posed by contaminants remaining in INTEC high-level waste management facilities over the long term (10,000 years) following ultimate dispositioning of those facilities. This section is organized such that a summary of the main risk assessment findings is presented first. Summary results are presented by facility closure scenario for each receptor category and principal exposure pathway. Detailed results are then presented separately for the radionuclides I-129 and Tc-99, and for the nonradiological contaminants of potential concern cadmium, fluoride and nitrate. These results also specify the dose for each receptor category from each source facility by principal exposure pathway, with supplemental detail provided for specific types or modes of exposure.

C.9.7.1 Summary

A summary of radiation dose is presented for each receptor and facility closure scenario in Table C.9-11. The doses reported in this table are lifetime doses in millirem. Table C.9-12 presents estimates of cancer risk resulting from the doses reported in Table C.9-11. These risks represent the number of excess cancer fatalities expected in a population of 1,000 people if all individuals in the population were exposed to the doses listed in Table C.9-11.

Doses are highest for receptor categories under the scenarios that involve either exposure to air releases from a bin set system under the No Action alternative, or exposure to groundwater releases after disposal of Class C grout in INEEL facilities (either in the Tank Farm and bin sets or in a new low-activity waste disposal facility). For all receptors except the INEEL worker and intruders, doses from the groundwater pathway are primarily due to I-129 intake via groundwater and food product ingestion. Even under very conservative assumptions (i.e., the maximally exposed resident), these doses are small fractions of those received from natural background sources (typically about 360 millirem per year). Intruder and INEEL worker doses and risks result mainly from external exposure to radionuclides in closed facilities. For intruders, the dose would be highest under the alternative involving disposal of Class C grout in the Tank Farm and bin sets, while for INEEL workers it would be very low in all cases but highest under the No Action scenario. The magnitude of these external dose estimates is highly influenced by assumed occupancy times and proximity to the bin sets. Under the conditions assumed here, the maximum intruder dose is estimated at about 3 millirem, while the maximum INEEL worker dose would be a small fraction of a millirem.

Table C.9-9. Parameter values and summary intake factors used in the facility disposition human health risk assessment.

Exposure parameter	Units	Maximum resident farmer	Average resident farmer	Future construction worker	Indoor worker	Uninformed intruder[a]	Recreational user
Receptor characteristics							
Body weight – adult	kg	70	70	70	70	70	70
Body weight – adolescent	kg	-[b]	-	-	-	-	-
Body weight – child	kg	15	-	-	-	-	-
Averaging time: carcinogens	y	70	70	70	70	70	70
Groundwater ingestion							
Exposure duration	y	30	9	25	25	-	24
Exposure period	d/y	350	280	250	250	-	14
Averaging time: noncarcinogens	y	30	9	25	25	-	24
Groundwater intake rate	liter/d	2	1.4	1	1	-	2
SIF[c] – carcinogens	liter/kg-d	0.012	2.0×10^{-3}	3.0×10^{-3}	3.0×10^{-3}	-	3.8×10^{-4}
SIF – noncarcinogens	liter/kg-d	0.027	0.015	0.01	0.01	-	1.1×10^{-3}
SIF – radionuclides	liters	2.1×10^{4}	3.5×10^{3}	6.3×10^{3}	6.3×10^{3}	-	672
Soil ingestion							
Exposure duration - as adult	y	24	9	25	25	1	24
Exposure duration - as child	d/y	6	-	-	-	-	-
Exposure frequency	d/y	350	275	250	250	1	14
Averaging time: noncarcinogens	y	30	9	25	25	25	24
Soil intake rate - adult	mg/d	100	100	100	50	1.0×10^{-4}	1.0×10^{-4}
Soil intake rate - child	mg/d	200	-	-	-	-	-
SIF – carcinogens	kg/kg-d	$1.6.\times10^{-6}$	$1.4.\times10^{-7}$	$3.5.\times10^{-7}$	$1.7.\times10^{-7}$	1.1×10^{-5}	$1.9.\times10^{-8}$
SIF – noncarcinogens	kg/kg-d	3.7×10^{-6}	1.1×10^{-6}	9.8×10^{-7}	4.9×10^{-7}	1.0×10^{-3}	5.5×10^{-8}
SIF – radionuclides	kg	1.3	0.25	0.63	0.31	1.0×10^{-4}	0.034
Fugitive dust inhalation							
Exposure duration	y	30	9	25	25	1	24
Exposure frequency	d/y	350	275	250	250	1	14
Averaging time: noncarcinogens	y	30	9	25	25	25	24
Inhalation rate - outdoors	m^3/d	20	20	20	7.2	20	20
Particulate loading factor	kg/m^3	1.4×10^{-8}	1.4×10^{-8}	1.4×10^{-8}	1.4×10^{-8}	1.4×10^{-8}	1.4×10^{-8}
SIF – carcinogens	m^3/kg-d	0.12	0.028	0.07	0.05	0.10	3.8×10^{-3}
SIF – noncarcinogens	m^3/kg-d	0.27	0.22	0.20	0.15	1.4×10^{-7}	0.011
SIF – radionuclides	m^3	2.1×10^{5}	5.0×10^{4}	1.3×10^{5}	4.5×10^{4}	20	6.7×10^{3}
Dermal absorption							
Soil							
Exposure duration - child	y	6	-	-	-	-	-
Exposure duration - adult	y	24	9	25	-	-	24
Exposure frequency	d/y	350	275	250	-	-	14
Averaging time: noncarcinogens	y	30	9	25	-	-	24
Contact rate - child	mg/cm^2	0.30	-	-	-	-	-
Contact rate - adult	mg/cm^2	0.08	0.08	0.08	-	-	0.08
Skin surface area - child	cm^2	3.9×10^{3}	-	-	-	-	-
Skin surface area - adult/summer	cm^2	5.0×10^{3}	5.0×10^{3}	5.0×10^{3}	-	-	5.0×10^{3}
Skin surface area - adult/winter	cm^2	1.9×10^{3}	1.9×10^{3}	1.9×10^{3}	-	-	1.9×10^{3}
Skin surface area – adult weighted average	cm^2	2.7×10^{3}	2.7×10^{3}	2.7×10^{3}	-	-	2.7×10^{3}
Correction factor	kg/mg	1.0×10^{-6}	1.0×10^{-6}	1.0×10^{-6}	-	-	1.0×10^{-6}

Table C.9-9. Parameter values and summary intake factors used in the facility disposition human health risk assessment (continued).

Exposure parameter	Units	Maximum resident farmer	Average resident farmer	Future construction worker	Indoor worker	Uninformed intruder[a]	Recreational user
Dermal absorption (Continued)							
Soil (Continued)							
SIF – carcinogens	kg/kg-d	7.4×10^{-7}	3.0×10^{-8}	7.5×10^{-8}	-	-	4.0×10^{-9}
SIF – noncarcinogens	kg/kg-d	1.7×10^{-6}	2.3×10^{-7}	1.7×10^{-7}	-	-	9.4×10^{-9}
SIF – radionuclides	kg	0.92	0.4	1.7	-	-	-
Groundwater							
Exposure duration	y	30	9	25	25	-	24
Exposure frequency	d/y	350	280	250	250	-	14
Averaging time: noncarcinogens	y	30	9	25	25	-	24
Contact rate	hr	0.17	0.12	0.17	0.17	-	0.17
Skin surface area	cm^2	2.0×10^{4}	2.0×10^{4}	2.0×10^{4}	2.0×10^{4}	-	2.0×10^{4}
Permeability factor	cm/hr	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	-	1.0×10^{-3}
Correction factor	liter/cm^3	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	-	1.0×10^{-3}
SIF – carcinogens	liter/kg-d	2.0×10^{-5}	3.3×10^{-6}	1.2×10^{-5}	$1.2.\times10^{-5}$	-	6.4×10^{-7}
SIF – noncarcinogens	liter/kg-d	4.7×10^{-5}	2.6×10^{-5}	2.8×10^{-5}	$2.8.\times10^{-5}$	-	1.5×10^{-6}
SIF – radionuclides	liters	36	5.9	21	-	-	-
Food product consumption							
Exposure duration - as adult	y	24	9	-	-	-	24
Exposure duration - as child	d/y	6	-	-	-	-	-
Exposure frequency	d/y	350	280	-	-	-	30
Averaging time: noncarcinogens	y	30	9	-	-	-	24
Root crops and other vegetables and fruits							
Crop intake rate - adult	kg/d	0.39	0.39	-	-	-	-
Crop intake rate - child	kg/d	0.32	-	-	-	-	-
SIF – carcinogens	kg/kg-d	3.6×10^{-3}	5.4×10^{-4}	-	-	-	-
SIF – noncarcinogens	kg/kg-d	8.4×10^{-3}	4.2×10^{-3}	-	-	-	-
SIF – radionuclides	kg	3.9×10^{3}	960	-	-	-	-
Leafy vegetables							
Crop intake rate - adult	kg/d	0.05	0.05	-	-	-	-
Crop intake rate - child	kg/d	0.02	-	-	-	-	-
SIF – carcinogens	kg/kg-d	3.4×10^{-4}	6.9×10^{-5}	-	-	-	-
SIF – noncarcinogens	kg/kg-d	8.0×10^{-4}	5.4×10^{-4}	-	-	-	-
SIF – radionuclides	kg	460	120	-	-	-	-
Grains							
Grain intake rate - adult	kg/d	0.097	0.097	-	-	-	-
Grain intake rate - child	kg/d	0.087	-	-	-	-	-
SIF – carcinogens	kg/kg-d	9.3×10^{-4}	1.3×10^{-4}	-	-	-	-
SIF – noncarcinogens	kg/kg-d	2.2×10^{-3}	1.0×10^{-3}	-	-	-	-
SIF – radionuclides	kg	1.0×10^{3}	240	-	-	-	-
Meat							
Meat intake rate - adult	kg/d	0.23	0.23	-	-	-	0.23
Meat intake rate - child	kg/d	0.12	-	-	-	-	-
SIF - carcinogens	kg/kg-d	1.7×10^{-3}	3.2×10^{-4}	-	-	-	6.2×10^{-5}
SIF - noncarcinogens	kg/kg-d	4.1×10^{-3}	2.5×10^{-3}	-	-	-	1.4×10^{-4}
SIF - radionuclides	kg	2.2×10^{3}	570	-	-	-	170

Table C.9-9. Parameter values and summary intake factors used in the facility disposition human health risk assessment (continued).

Exposure parameter	Units	Maximum resident farmer	Average resident farmer	Future construction worker	Indoor worker	Uninformed intruder[a]	Recreational user
Food product consumption (Continued)							
Poultry							
Poultry intake rate - adult	kg/d	0.026	0.026	-	-	-	-
Poultry intake rate - child	kg/d	0.018	-	-	-	-	-
SIF - carcinogens	kg/kg-d	2.2×10^{-4}	3.6×10^{-5}	-	-	-	-
SIF - noncarcinogens	kg/kg-d	5.2×10^{-4}	2.8×10^{-4}	-	-	-	-
SIF - radionuclides	kg	260	64	-	-	-	-
Milk and milk products							
Milk product intake rate - adult	liter/d	0.31	0.31	-	-	-	-
Milk product intake rate - child	liter/d	0.61	-	-	-	-	-
SIF - carcinogens	liter/kg-d	4.8×10^{-3}	4.2×10^{-4}	-	-	-	-
SIF - noncarcinogens	liter/kg-d	0.011	3.3×10^{-3}	-	-	-	-
SIF - radionuclides	liters	3.8×10^{3}	760	-	-	-	-
Eggs							
Egg intake rate - adult	kg/d	0.041	0.041	-	-	-	-
Egg intake rate - child	kg/d	0.025	-	-	-	-	-
SIF - carcinogens	kg/kg-d	3.3×10^{-4}	5.7×10^{-5}	-	-	-	-
SIF - noncarcinogens	kg/kg-d	7.7×10^{-4}	4.4×10^{-4}	-	-	-	-
SIF - radionuclides	kg	400	100	-	-	-	-
Direct radiation exposure							
Contaminated soil							
Exposure duration	y	30	30	25	25	1	24
Exposure frequency	d/y	350	350	250	250	1	14
Contact rate	h/d	24	24	8	8	24	24
Soil concentration	pCi/g	5.6×10^{-4}	5.6×10^{-4}	5.6×10^{-4}	5.6×10^{-4}	5.6×10^{-4}	5.6×10^{-4}
SIF - radionuclides	pCi-h/g	140	140	28	28	0.013	4.5
Closed facilities							
Exposure duration	y	30	30	25	30	1	24
Exposure frequency	d/y	350	350	250	350	1	14
Contact rate	h/d	24	24	8	8	24	24
SIF – radionuclides	h	2.0×10^{4}	2.0×10^{4}	5.0×10^{4}	8.4×10^{4}	24	8.1×10^{3}

a. Intruder after the period of institutional control over INEEL.
b. Dash indicates that the exposure parameter was not used in the case indicated.
c. SIF = Summary intake factor.

Table C.9-11. Summary of total lifetime radiation dose (millirem) from exposure to radionuclides according to receptor and facility disposition alternative.

	Facility disposition alternative					
Receptor	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer	8.7[a]	13	18	50	21	51
Average resident farmer	4.8	2.7	3.7	10	4.2	10
INEEL worker	5.3	8.9×10^{-11}	9.0×10^{-11}	3.8×10^{-9}	8.9×10^{-11}	9.1×10^{-11}
Construction worker	1.4	1.4	2	5.4	2.2	5.4
Indoor worker	1.4	1.4	2	5.4	2.2	5.4
Unauthorized Intruder[b]	0.29	0.023	2.4×10^{-3}	1.5	0.023	0.023
Uninformed Intruder[c]	0.047	3.8×10^{-3}	7.7×10^{-3}	0.25	3.8×10^{-3}	3.8×10^{-3}
Recreational user	0.22	0.31	0.42	1.2	0.48	1.2

a. An air pathway dose of 170 millirem is calculated based on the maximally exposed individual dose due to failure of a single bin set system.
b. Time frame for receptor exposure is during period of institutional control.
c. Time frame for receptor exposure is distant future.

Table C.9-12. Summary of excess carcinogenic risk (cancer fatalities per thousand persons) from exposure to radionuclides according to receptor and facility disposition alternative.

	Facility disposition alternative					
Receptor	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer	4.4×10^{-3}[(a)]	6.7×10^{-3}	9.2×10^{-3}	0.025	0.01	0.025
Average resident farmer	2.4×10^{-3}	1.4×10^{-3}	1.9×10^{-3}	5.1×10^{-3}	2.1×10^{-3}	5.1×10^{-3}
INEEL worker	2.7×10^{-3}	4.5×10^{-14}	4.5×10^{-14}	1.9×10^{-12}	4.5×10^{-14}	4.5×10^{-14}
Construction worker	6.9×10^{-4}	7.2×10^{-4}	9.8×10^{-4}	2.7×10^{-3}	1.1×10^{-3}	2.7×10^{-3}
Indoor worker	6.8×10^{-4}	7.2×10^{-4}	9.8×10^{-4}	2.7×10^{-3}	1.1×10^{-3}	2.7×10^{-3}
Unauthorized Intruder [b]	1.4×10^{-4}	1.1×10^{-5}	1.2×10^{-6}	7.5×10^{-4}	1.1×10^{-5}	1.1×10^{-5}
Uninformed Intruder [c]	2.4×10^{-5}	1.9×10^{-6}	3.9×10^{-6}	1.3×10^{-4}	1.9×10^{-6}	1.9×10^{-6}
Recreational user	1.1×10^{-4}	1.5×10^{-4}	2.1×10^{-4}	5.8×10^{-4}	2.4×10^{-4}	5.8×10^{-4}

a. The risk from radiation dose due to failure of a single bin set is calculated to be 0.085 latent cancer fatalities for an assumed population of 1000 persons.
b. Time frame for receptor exposure is during period of institutional control.
c. Time frame for receptor exposure is distant future.

Nonradiological risks are reported both for cancer and noncancer health effects. Cancer risk is reported in terms of probability of individual excess cancer resulting from lifetime exposure. In the cases assessed here, cancer risk results only from inhalation of cadmium entrained in fugitive dust. Noncancer effects are reported in terms of a health hazard quotient, which is the ratio of the contaminants of potential concern intake to the applicable inhalation or oral reference dose. A hazard quotient of greater than unity indicates that the intake is higher than the reference value. Noncancer risk is incurred from intake of cadmium via ingestion, inhalation and dermal absorption, and fluorides and nitrates via ingestion and dermal absorption.

For all receptors and scenarios, cancer risk from cadmium exposure is very low (less than one in a trillion). Noncancer risk would be higher for some receptors and scenarios, most notably those cases involving fluoride releases from landfill disposal of Class A or C grout. In those cases, a hazard quotient of 1.5 is estimated for the maximally exposed resident farmer, due mainly to ingestion of fluoride in groundwater and food products irrigated or raised with contaminated groundwater. The effect of concern for fluoride intake is objectionable dental fluorosis, which is considered more of a cosmetic effect than an adverse health effect (EPA 1998). Table C.9-13 presents a summary of noncancer hazard quotients for intakes of fluoride, nitrate, and cadmium.

Table C.9-13. Summary of estimated noncarcinogenic health hazard quotients from exposure to nonradiological contaminants according to receptor and facility disposition alternative.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance -Based Closure with Class A Grout Disposal	Performance -Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Health hazard quotient due to cadmium intake						
Maximally exposed resident farmer	4.3×10^{-7}	6.5×10^{-8}	4.6×10^{-7}	4.8×10^{-7}	1.5×10^{-5}	1.6×10^{-5}
Average resident farmer	6.7×10^{-8}	1.0×10^{-8}	7.1×10^{-8}	7.5×10^{-8}	2.3×10^{-6}	2.5×10^{-6}
Construction worker	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Indoor worker	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Recreational user	3.7×10^{-9}	1.2×10^{-9}	8.7×10^{-9}	9.1×10^{-9}	2.8×10^{-7}	3.1×10^{-7}
Health hazard quotient due to fluoride intake						
Maximally exposed resident farmer	0.08	5.2×10^{-4}	0.12	0.27	1.4	1.4
Average resident farmer	0.04	2.6×10^{-4}	0.058	0.13	0.69	0.71
Construction worker	6.4×10^{-3}	4.2×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Indoor worker	6.4×10^{-3}	4.2×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Recreational user	1.8×10^{-3}	1.2×10^{-5}	2.6×10^{-3}	4.1×10^{-3}	0.032	0.032
Health hazard quotient due to nitrate intake						
Maximally exposed resident farmer	6.5×10^{-3}	3.0×10^{-5}	1.1×10^{-4}	1.1×10^{-4}	3.0×10^{-5}	3.0×10^{-5}
Average resident farmer	2.9×10^{-3}	1.3×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	1.3×10^{-5}	1.3×10^{-5}
Construction worker	4.0×10^{-4}	1.9×10^{-6}	7.1×10^{-6}	7.1×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Indoor worker	4.0×10^{-4}	1.9×10^{-6}	7.1×10^{-6}	7.1×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Recreational user	8.4×10^{-5}	3.9×10^{-7}	1.5×10^{-6}	1.5×10^{-6}	3.9×10^{-7}	3.9×10^{-7}

C.9.7.2 Radiological Risk

Radiation exposure and attendant risk could be incurred from three major pathways: radionuclide releases to, and subsequent use of, groundwater resources; exposure to sources of direct (external) radiation; and airborne radionuclide releases. The latter pathway is described in Section 5.2.14 and is not evaluated in this appendix. Exposures that ultimately result from groundwater releases represent the greatest contributor to risk for all cases except for a near-term intruder scenario, in which external radiation from the dispositioned Tank Farm or bin sets (through compromised shielding) becomes the predominant source. Within the groundwater release pathway, the main sources of radionuclide intake are:

- Ingestion of groundwater (which is assumed to be the primary source of drinking water)
- Consumption of food crops irrigated with groundwater
- Consumption of food products (meat, milk and eggs) from animals which are watered with groundwater and fed with grain irrigated with groundwater

The doses and risks are primarily due to I-129, and this exposure would occur about 1,000 years into the future. Intakes of Tc-99 are only feasible farther into the future (about 10,000 years), due to the longer migration period required for this nuclide to reach the aquifer. In general, doses and risks from Tc-99 are much lower than those from I-129. Doses from the groundwater release pathway are presented in Table C.9-14 for I-129 and Table C.9-15 for Tc-99.

C.9.7.3 Nonradiological Health Risk

The screening evaluation identified cadmium, fluorides and nitrates as the only nonradiological contaminants of potential concern that would be released to groundwater in quantities potentially approaching drinking water standards. Of these, fluoride and nitrate intakes would occur over the same time frame (a few to several hundred years hence). Cadmium would migrate through the vadose zone at a much slower pace, and credible human exposure scenarios are not credible until a few thousand years later, by which time the other contaminants are no longer present. The health risk assessment results for each of these contaminants of potential concern are presented and discussed in this section.

Cadmium is considered a human carcinogen if inhaled, but data are not available to support cancer risk quantitation for other intake modes such as ingestion or dermal absorption (EPA 1998). The inhalation

Table C.9-14. Lifetime radiation dose (millirem) by receptor and disposition alternative for I-129 released to groundwater.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer						
Groundwater ingestion	1.4	4.8	6.6	18	7.5	18
Soil ingestion	2.0×10^{-5}	7.0×10^{-5}	9.6×10^{-5}	2.6×10^{-4}	1.1×10^{-4}	2.6×10^{-4}
Food product consumption:						
Other vegetables and fruit	0.15	0.5	0.69	1.9	0.79	1.9
Leafy vegetables	0.15	0.51	0.7	1.9	0.8	1.9
Grain	0.085	0.29	0.4	1.1	0.46	1.1
Meat (beef)	0.59	2	2.8	7.7	3.2	7.7
Poultry	1.5×10^{-7}	5.1×10^{-7}	7.0×10^{-7}	1.9×10^{-6}	8.0×10^{-7}	1.9×10^{-6}
Milk and milk products	1.5	5.2	7.1	19	8.1	19
Eggs	0.036	0.12	0.17	0.46	0.19	0.46
Subtotal - food ingestion	2.5	8.7	12	32	13	33
Dermal contact with:						
Soil	1.5×10^{-5}	5.1×10^{-5}	7.0×10^{-5}	1.9×10^{-4}	7.9×10^{-5}	1.9×10^{-4}
Groundwater	2.4×10^{-3}	8.2×10^{-3}	0.011	0.031	0.013	0.031
Subtotal - skin absorption	2.4×10^{-3}	8.2×10^{-3}	0.011	0.031	0.013	0.031
Fugitive dust inhalation	3.0×10^{-8}	1.0×10^{-7}	1.4×10^{-7}	3.8×10^{-7}	1.6×10^{-7}	3.9×10^{-7}
Direct radiation exposure from:						
Soil concentration	5.3×10^{-11}	1.8×10^{-10}	2.5×10^{-10}	6.8×10^{-10}	2.8×10^{-10}	6.8×10^{-10}
Buried sources	4.8	6.4×10^{-11}	1.1×10^{-10}	2.8×10^{-9}	6.4×10^{-11}	6.5×10^{-11}
Subtotal - direct radiation	4.8	2.5×10^{-10}	3.6×10^{-10}	3.4×10^{-9}	3.5×10^{-10}	7.5×10^{-10}
Total scenario	8.7	13	18	50	21	51
Average resident						
Groundwater ingestion	0.23	0.79	1.1	3	1.2	3
Soil ingestion	4.0×10^{-6}	1.4×10^{-5}	1.9×10^{-5}	5.1×10^{-5}	2.1×10^{-5}	5.2×10^{-5}
Food product consumption:						
Other vegetables and fruit	0.036	0.12	0.17	0.46	0.19	0.46
Leafy vegetables	0.04	0.14	0.19	0.51	0.21	0.52
Grain	0.02	0.071	0.096	0.26	0.11	0.27
Meat (beef)	0.16	0.53	0.73	2	0.83	2
Poultry	3.7×10^{-5}	1.3×10^{-4}	1.8×10^{-4}	4.8×10^{-4}	2.0×10^{-4}	4.8×10^{-4}
Milk and milk products	0.3	1	1.4	3.8	1.6	3.8
Eggs	9.1×10^{-3}	0.031	0.043	0.12	0.049	0.12
Subtotal - food ingestion	0.56	1.9	2.6	7.2	3	7.2

Table C.9-14. Lifetime radiation dose (millirem) by receptor and disposition alternative for I-129 released to groundwater (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Dermal contact with:						
Soil	6.4×10^{-6}	2.2×10^{-5}	3.0×10^{-5}	8.2×10^{-5}	3.4×10^{-5}	8.3×10^{-5}
Groundwater	4.0×10^{-4}	1.4×10^{-3}	1.9×10^{-3}	5.1×10^{-3}	2.1×10^{-3}	5.1×10^{-3}
Subtotal - skin absorption	4.0×10^{-4}	1.4×10^{-3}	1.9×10^{-3}	5.2×10^{-3}	2.2×10^{-3}	5.2×10^{-3}
Fugitive dust inhalation	7.0×10^{-9}	2.4×10^{-8}	3.3×10^{-8}	9.1×10^{-8}	3.8×10^{-8}	9.1×10^{-8}
Direct radiation exposure from:						
Soil concentration	5.3×10^{-11}	1.8×10^{-10}	2.5×10^{-10}	6.8×10^{-10}	2.8×10^{-10}	6.8×10^{-10}
Buried sources	4	6.4×10^{-11}	1.1×10^{-10}	2.8×10^{-9}	6.4×10^{-11}	6.5×10^{-11}
Subtotal - direct radiation	4	2.5×10^{-10}	3.6×10^{-10}	3.4×10^{-9}	3.5×10^{-10}	7.5×10^{-10}
Total scenario	4.8	2.7	3.7	10	4.2	10
INEEL worker						
Direct radiation exposure from:						
Soil concentration	-	-	-	-	-	-
Buried sources	5.3	8.9×10^{-11}	1.8×10^{-10}	3.9×10^{-9}	8.9×10^{-11}	9.1×10^{-11}
Total scenario	5.3	8.9×10^{-11}	1.8×10^{-10}	3.9×10^{-9}	8.9×10^{-11}	9.1×10^{-11}
Construction worker						
Groundwater ingestion	0.42	1.4	2	5.4	2.2	5.4
Soil ingestion	1.0×10^{-5}	3.5×10^{-5}	4.7×10^{-5}	1.3×10^{-4}	5.4×10^{-5}	1.3×10^{-4}
Dermal contact with:						
Soil	2.7×10^{-5}	9.3×10^{-5}	1.3×10^{-4}	3.5×10^{-4}	1.4×10^{-4}	3.5×10^{-4}
Groundwater	1.4×10^{-3}	4.9×10^{-3}	6.7×10^{-3}	0.018	7.6×10^{-3}	0.018
Subtotal – skin absorption	1.4×10^{-3}	5.0×10^{-3}	6.8×10^{-3}	0.019	7.7×10^{-3}	0.019
Direct radiation exposure from:						
Soil concentration	1.0×10^{-11}	3.6×10^{-11}	4.9×10^{-11}	1.3×10^{-10}	5.6×10^{-11}	1.4×10^{-10}
Buried sources	0.96	1.3×10^{-11}	2.2×10^{-11}	5.5×10^{-10}	1.3×10^{-11}	1.3×10^{-11}
Subtotal - direct radiation	0.96	4.9×10^{-11}	7.1×10^{-11}	6.8×10^{-10}	6.9×10^{-11}	1.5×10^{-10}
Total scenario	1.4	1.4	2	5.4	2.2	5.4
Indoor worker						
Groundwater ingestion	0.42	1.4	2	5.4	2.2	5.4
Soil ingestion	5.0×10^{-6}	1.7×10^{-5}	2.4×10^{-5}	6.5×10^{-5}	2.7×10^{-5}	6.5×10^{-5}
Fugitive dust inhalation	6.4×10^{-9}	2.2×10^{-8}	3.0×10^{-8}	8.2×10^{-8}	3.4×10^{-8}	8.3×10^{-8}
Direct radiation exposure from:						
Soil concentration	1.0×10^{-11}	3.6×10^{-11}	4.9×10^{-11}	1.3×10^{-10}	5.6×10^{-11}	1.4×10^{-10}
Buried sources	0.95	1.5×10^{-11}	2.6×10^{-11}	6.6×10^{-10}	1.5×10^{-11}	1.6×10^{-11}
Subtotal - direct radiation	0.95	5.1×10^{-11}	7.5×10^{-11}	7.9×10^{-10}	7.1×10^{-11}	1.5×10^{-10}
Total scenario	1.4	1.4	2	5.4	2.2	5.4

Table C.9-14. Lifetime radiation dose (millirem) by receptor and disposition alternative for I-129 released to groundwater (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Unauthorized intruder						
Direct radiation exposure from:						
Soil concentration	-	-	-	-	-	-
Buried sources	0.29	0.023	0.025	1.5	0.023	0.023
Total scenario	0.29	0.023	0.025	1.5	0.023	0.023
Uninformed intruder						
Soil ingestion	1.6×10^{-9}	5.5×10^{-9}	7.6×10^{-9}	2.1×10^{-8}	8.6×10^{-9}	2.1×10^{-8}
Fugitive dust inhalation	2.8×10^{-12}	9.8×10^{-12}	1.3×10^{-11}	3.7×10^{-11}	1.5×10^{-11}	3.7×10^{-11}
Direct radiation exposure from:						
Soil concentration	5.0×10^{-15}	1.7×10^{-14}	2.4×10^{-14}	6.5×10^{-14}	2.7×10^{-14}	6.5×10^{-14}
Buried sources	0.047	3.8×10^{-3}	7.7×10^{-3}	0.25	3.8×10^{-3}	3.8×10^{-3}
Subtotal - direct radiation	0.047	3.8×10^{-3}	7.7×10^{-3}	0.25	3.8×10^{-3}	3.8×10^{-3}
Total scenario	0.047	3.8×10^{-3}	7.7×10^{-3}	0.25	3.8×10^{-3}	3.8×10^{-3}
Recreational user						
Groundwater ingestion	0.045	0.15	0.21	0.58	0.24	0.58
Soil ingestion	5.4×10^{-7}	1.9×10^{-6}	2.5×10^{-6}	7.0×10^{-6}	2.9×10^{-6}	7.0×10^{-6}
Meat ingestion	0.045	0.16	0.21	0.58	0.24	0.59
Fugitive dust inhalation	9.5×10^{-10}	3.3×10^{-9}	4.5×10^{-9}	1.2×10^{-8}	5.1×10^{-9}	1.2×10^{-8}
Direct radiation exposure from:						
Soil concentration	1.7×10^{-12}	5.8×10^{-12}	7.9×10^{-12}	2.2×10^{-11}	9.1×10^{-12}	2.2×10^{-11}
Buried sources	0.13	2.0×10^{-12}	3.5×10^{-12}	8.8×10^{-11}	2.0×10^{-12}	2.1×10^{-12}
Subtotal - direct radiation	0.13	7.9×10^{-12}	1.1×10^{-11}	1.1×10^{-10}	1.1×10^{-11}	2.4×10^{-11}
Total scenario	0.22	0.31	0.42	1.2	0.48	1.2

cancer slope factor is 6.3 (mg/kg-d)$^{-1}$. The limiting noncancer effect of cadmium intake is proteinuria (excessive excretion of protein in the urine), and EPA has established a Reference Dose (RfD) based on this effect, as well as an RfD for chronic inhalation of cadmium. The RfD for oral intake is 5.0×10^{-4} mg/kg-d, while the RfD for inhalation is 5.7×10^{-5} mg/kg-d. For all receptors and scenarios, the cancer risk from cadmium inhalation is very low (less than one in a trillion). Table C.9-16 lists the cadmium noncancer hazard quotient by receptor, principal pathway and closure scenario.

The effect of concern for fluoride intake is objectionable dental fluorosis. This effect, which is considered more of a cosmetic effect than an adverse health effect, can result from exposure to high fluoride levels during childhood. Dental fluorosis can involve mottling, discoloration, and in some cases pitting of the teeth. The EPA has established an oral RfD of 0.06 mg/kg-d, based on prevention of dental

Table C.9-15. Lifetime radiation dose (millirem) by receptor and facility disposition alternative for Tc-99 released to groundwater.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer						
Groundwater ingestion	7.5×10^{-3}	4.6×10^{-4}	4.7×10^{-4}	4.8×10^{-4}	1.4×10^{-3}	2.4×10^{-3}
Soil ingestion	2.0×10^{-6}	1.2×10^{-7}	1.2×10^{-7}	1.3×10^{-7}	3.7×10^{-7}	6.3×10^{-7}
Food product consumption:						
Other vegetables and fruit	0.25	0.015	0.016	0.016	0.046	0.079
Leafy vegetables	0.03	1.8×10^{-3}	1.9×10^{-3}	1.9×10^{-3}	5.5×10^{-3}	9.5×10^{-3}
Grain	0.063	3.9×10^{-3}	3.9×10^{-3}	4.0×10^{-3}	0.012	0.02
Meat (beef)	9.8×10^{-3}	6.0×10^{-4}	6.1×10^{-4}	6.2×10^{-4}	1.8×10^{-3}	3.1×10^{-3}
Poultry	6.1×10^{-8}	3.7×10^{-9}	3.8×10^{-9}	3.8×10^{-9}	1.1×10^{-8}	1.9×10^{-8}
Milk and milk products	0.014	8.6×10^{-4}	8.7×10^{-4}	8.8×10^{-4}	2.6×10^{-3}	4.4×10^{-3}
Eggs	9.4×10^{-3}	5.8×10^{-4}	5.9×10^{-4}	6.0×10^{-4}	1.7×10^{-3}	3.0×10^{-3}
Subtotal - food ingestion	0.38	0.023	0.023	0.024	0.069	0.12
Dermal contact with:						
Soil	4.8×10^{-6}	3.0×10^{-7}	3.0×10^{-7}	3.1×10^{-7}	8.9×10^{-7}	1.5×10^{-6}
Groundwater	1.3×10^{-5}	7.8×10^{-7}	8.0×10^{-7}	8.1×10^{-7}	2.4×10^{-6}	4.1×10^{-6}
Subtotal - skin absorption	1.8×10^{-5}	1.1×10^{-6}	1.1×10^{-6}	1.1×10^{-6}	3.3×10^{-6}	5.6×10^{-6}
Fugitive dust inhalation	2.6×10^{-8}	1.6×10^{-9}	1.6×10^{-9}	1.7×10^{-9}	4.9×10^{-9}	8.3×10^{-9}
Direct radiation exposure from:						
Soil concentration	8.4×10^{-6}	5.1×10^{-7}	5.2×10^{-7}	5.3×10^{-7}	1.6×10^{-6}	2.7×10^{-6}
Buried sources	4.8	6.4×10^{-11}	1.1×10^{-10}	2.8×10^{-9}	6.4×10^{-11}	6.5×10^{-11}
Subtotal - direct radiation	4.8	5.1×10^{-7}	5.2×10^{-7}	5.3×10^{-7}	1.6×10^{-6}	2.7×10^{-6}
Total scenario	5.2	0.023	0.024	0.024	0.071	0.12
Average resident						
Groundwater ingestion	1.2×10^{-3}	7.6×10^{-5}	7.8×10^{-5}	7.9×10^{-5}	2.3×10^{-4}	3.9×10^{-4}
Soil ingestion	3.9×10^{-7}	2.4×10^{-8}	2.4×10^{-8}	2.5×10^{-8}	7.2×10^{-8}	1.2×10^{-7}
Food product consumption:						
Other vegetables and fruit	0.061	3.7×10^{-3}	3.8×10^{-3}	3.8×10^{-3}	0.011	0.019
Leafy vegetables	8.0×10^{-3}	4.9×10^{-4}	5.0×10^{-4}	5.1×10^{-4}	1.5×10^{-3}	2.5×10^{-3}
Grain	0.015	9.3×10^{-4}	9.5×10^{-4}	9.6×10^{-4}	2.8×10^{-3}	4.8×10^{-3}
Meat (beef)	2.6×10^{-3}	1.6×10^{-4}	1.6×10^{-4}	1.6×10^{-4}	4.7×10^{-4}	8.1×10^{-4}
Poultry	1.5×10^{-5}	9.4×10^{-7}	9.5×10^{-7}	9.7×10^{-7}	2.8×10^{-6}	4.8×10^{-6}
Milk and milk products	2.8×10^{-3}	1.7×10^{-4}	1.7×10^{-4}	1.7×10^{-4}	5.1×10^{-4}	8.7×10^{-4}
Eggs	2.4×10^{-3}	1.5×10^{-4}	1.5×10^{-4}	1.5×10^{-4}	4.4×10^{-4}	7.6×10^{-4}
Subtotal - food ingestion	0.092	5.6×10^{-3}	5.7×10^{-3}	5.8×10^{-3}	0.017	0.029
Dermal contact with:						
Soil	6.3×10^{-7}	3.8×10^{-8}	3.9×10^{-8}	4.0×10^{-8}	1.2×10^{-7}	2.0×10^{-7}
Groundwater	2.1×10^{-6}	1.3×10^{-7}	1.3×10^{-7}	1.3×10^{-7}	3.9×10^{-7}	6.7×10^{-7}
Subtotal - skin absorption	2.8×10^{-6}	1.7×10^{-7}	1.7×10^{-7}	1.7×10^{-7}	5.1×10^{-7}	8.7×10^{-7}

Table C.9-15. Lifetime radiation dose (millirem) by receptor and facility disposition alternative for Tc-99 released to groundwater (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Fugitive dust inhalation	6.2×10^{-9}	3.8×10^{-10}	3.9×10^{-10}	3.9×10^{-10}	1.1×10^{-9}	2.0×10^{-9}
Direct radiation exposure from:						
Soil concentration	8.4×10^{-6}	5.1×10^{-7}	5.2×10^{-7}	5.3×10^{-7}	1.6×10^{-6}	2.7×10^{-6}
Buried sources	4	5.9×10^{-11}	1.0×10^{-10}	2.8×10^{-9}	5.9×10^{-11}	6.0×10^{-11}
Subtotal - direct radiation	4	5.1×10^{-7}	5.2×10^{-7}	5.3×10^{-7}	1.6×10^{-6}	2.7×10^{-6}
Total scenario	4.1	5.7×10^{-3}	5.8×10^{-3}	5.9×10^{-3}	0.017	0.029
INEEL worker						
Direct radiation exposure from:						
Soil concentration	-	-	-	-	-	-
Buried sources	5.3	8.9×10^{-11}	1.8×10^{-10}	3.9×10^{-9}	8.9×10^{-11}	9.1×10^{-11}
Total scenario	5.3	8.9×10^{-11}	1.8×10^{-10}	3.9×10^{-9}	8.9×10^{-11}	9.1×10^{-11}
Construction worker						
Groundwater ingestion	2.2×10^{-3}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	4.1×10^{-4}	7.1×10^{-4}
Soil ingestion	9.8×10^{-7}	6.0×10^{-8}	6.1×10^{-8}	6.2×10^{-8}	1.8×10^{-7}	3.1×10^{-7}
Dermal contact with:						
Soil	2.6×10^{-6}	1.6×10^{-7}	1.6×10^{-7}	1.7×10^{-7}	4.9×10^{-7}	8.3×10^{-7}
Groundwater	7.6×10^{-6}	4.7×10^{-7}	4.8×10^{-7}	4.8×10^{-7}	1.4×10^{-6}	2.4×10^{-6}
Subtotal – skin absorption	1.0×10^{-5}	6.3×10^{-7}	6.4×10^{-7}	6.5×10^{-7}	1.9×10^{-6}	3.2×10^{-6}
Fugitive dust inhalation	1.6×10^{-8}	9.6×10^{-10}	9.8×10^{-10}	9.9×10^{-10}	2.9×10^{-9}	5.0×10^{-9}
Direct radiation exposure from:						
Soil concentration	1.7×10^{-6}	1.0×10^{-7}	1.0×10^{-7}	1.1×10^{-7}	3.1×10^{-7}	5.3×10^{-7}
Buried sources	0.96	1.2×10^{-11}	2.1×10^{-11}	5.5×10^{-10}	1.2×10^{-11}	1.2×10^{-11}
Subtotal - direct radiation	0.96	1.0×10^{-7}	1.0×10^{-7}	1.1×10^{-7}	3.1×10^{-7}	5.3×10^{-7}
Total scenario	0.96	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	4.2×10^{-4}	7.1×10^{-4}
Indoor worker						
Groundwater ingestion	2.2×10^{-3}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	4.1×10^{-4}	7.1×10^{-4}
Soil ingestion	4.9×10^{-7}	3.0×10^{-8}	3.1×10^{-8}	3.1×10^{-8}	9.1×10^{-8}	1.6×10^{-7}
Fugitive dust inhalation	5.6×10^{-9}	3.5×10^{-10}	3.5×10^{-10}	3.6×10^{-10}	1.0×10^{-9}	1.8×10^{-9}
Direct radiation exposure from:						
Soil concentration	1.7×10^{-6}	1.0×10^{-7}	1.0×10^{-7}	1.1×10^{-7}	3.1×10^{-7}	5.3×10^{-7}
Buried sources	0.95	1.4×10^{-11}	2.5×10^{-11}	6.6×10^{-10}	1.4×10^{-11}	1.4×10^{-11}
Subtotal - direct radiation	0.95	1.0×10^{-7}	1.0×10^{-7}	1.1×10^{-7}	3.1×10^{-7}	5.3×10^{-7}
Total scenario	0.95	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	4.1×10^{-4}	7.1×10^{-4}
Unauthorized intruder						
Direct radiation exposure from:						
Soil concentration	-	-	-	-	-	-
Buried sources	0.29	0.023	0.025	1.5	0.023	0.023
Total scenario	0.29	0.023	0.025	1.5	0.023	0.023

Table C.9-15. Lifetime radiation dose (millirem) by receptor and facility disposition alternative for Tc-99 released to groundwater (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Uninformed intruder						
Soil ingestion	1.6×10^{-10}	9.7×10^{-12}	9.8×10^{-12}	1.0×10^{-11}	2.9×10^{-11}	5.0×10^{-11}
Fugitive dust inhalation	2.5×10^{-12}	1.5×10^{-13}	1.6×10^{-13}	1.6×10^{-13}	4.6×10^{-13}	7.9×10^{-13}
Direct radiation exposure from:						
Soil concentration	8.0×10^{-10}	4.9×10^{-11}	5.0×10^{-11}	5.1×10^{-11}	1.5×10^{-10}	2.5×10^{-10}
Buried sources	0.047	6.9×10^{-15}	3.9×10^{-3}	0.25	2.8×10^{-12}	4.3×10^{-9}
Subtotal - direct radiation	0.047	4.9×10^{-11}	3.9×10^{-3}	0.25	1.5×10^{-10}	4.6×10^{-9}
Total scenario	0.047	5.9×10^{-11}	3.9×10^{-3}	0.25	1.8×10^{-10}	4.6×10^{-9}
Recreational user						
Groundwater ingestion	2.4×10^{-4}	1.5×10^{-5}	1.5×10^{-5}	1.5×10^{-5}	4.5×10^{-5}	7.6×10^{-5}
Soil ingestion	5.3×10^{-8}	3.2×10^{-9}	3.3×10^{-9}	3.3×10^{-9}	9.8×10^{-9}	1.7×10^{-8}
Meat ingestion	7.4×10^{-4}	4.6×10^{-5}	4.6×10^{-5}	4.7×10^{-5}	1.4×10^{-4}	2.4×10^{-4}
Fugitive dust inhalation	8.4×10^{-10}	5.2×10^{-11}	5.3×10^{-11}	5.3×10^{-11}	1.6×10^{-10}	2.7×10^{-10}
Direct radiation exposure from:						
Soil concentration	2.7×10^{-7}	1.6×10^{-8}	1.7×10^{-8}	1.7×10^{-8}	5.0×10^{-8}	8.5×10^{-8}
Buried sources	0.13	1.9×10^{-12}	3.3×10^{-12}	8.8×10^{-11}	1.9×10^{-12}	1.9×10^{-12}
Subtotal - direct radiation	0.13	1.6×10^{-8}	1.7×10^{-8}	1.7×10^{-8}	5.0×10^{-8}	8.5×10^{-8}
Total scenario	9.8×10^{-4}	6.0×10^{-5}	6.1×10^{-5}	6.2×10^{-5}	1.8×10^{-4}	3.1×10^{-4}

fluorosis (EPA 1998). An RfD for fluoride inhalation has not been established. A more severe effect of excess fluoride intake is crippling skeletal fluorosis, but this effect would require higher intake rates. The EPA has estimated that the required intake rate for this effect is 0.28 mg/kg-d for adults (EPA 1998). Table C.9-17 presents the fluoride health hazard quotient, based on dental fluorosis, according to receptor, principal pathway and closure scenario.

The RfD for nitrate is based on the critical effect of methemoglobinemia, a serious medical condition in which the oxygen-carrying capacity of the blood is reduced as a result of a reaction with nitrate ions. The EPA has established an RfD of 1.6 mg/kg-d for oral intake, but an RfD value for nitrate intake by inhalation has not been established (EPA 1998). Table C.9-18 presents the nitrate health hazard quotient by receptor, principal pathway and closure scenario.

The combined effects of concurrent intakes of contaminants of potential concern are determined by adding the hazard quotients for chemicals that affect the same organ system. The sum of hazard quotients obtained in this manner is called the health hazard index. Of the chemicals assessed here, however, only

Table C.9-16. Noncarcinogenic health hazard quotient for cadmium by receptor category, principal intake pathway and facility disposition alternative.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer						
Groundwater ingestion	2.3×10^{-7}	3.6×10^{-8}	2.5×10^{-7}	2.6×10^{-7}	8.1×10^{-6}	8.8×10^{-6}
Soil ingestion	7.5×10^{-12}	1.2×10^{-12}	8.1×10^{-12}	8.4×10^{-12}	2.6×10^{-10}	2.8×10^{-10}
Food ingestion	1.9×10^{-7}	3.0×10^{-8}	2.1×10^{-7}	2.2×10^{-7}	6.7×10^{-6}	7.3×10^{-6}
Skin absorption	4.0×10^{-10}	6.1×10^{-11}	4.3×10^{-10}	4.5×10^{-10}	1.4×10^{-8}	1.5×10^{-8}
Fugitive dust inhalation	8.3×10^{-14}	1.3×10^{-14}	8.9×10^{-14}	9.3×10^{-14}	2.9×10^{-12}	3.1×10^{-12}
Sum from all pathways	4.3×10^{-7}	6.5×10^{-8}	4.6×10^{-7}	4.8×10^{-7}	1.5×10^{-5}	1.6×10^{-5}
Average resident farmer						
Groundwater ingestion	3.9×10^{-8}	5.9×10^{-9}	4.1×10^{-8}	4.3×10^{-8}	1.3×10^{-6}	1.5×10^{-6}
Soil ingestion	6.7×10^{-13}	1.0×10^{-13}	7.1×10^{-13}	7.5×10^{-13}	2.3×10^{-11}	2.5×10^{-11}
Food ingestion	2.8×10^{-8}	4.3×10^{-9}	3.0×10^{-8}	3.1×10^{-8}	9.7×10^{-7}	1.1×10^{-6}
Skin absorption	6.6×10^{-11}	1.0×10^{-11}	7.1×10^{-11}	7.4×10^{-11}	2.3×10^{-9}	2.5×10^{-9}
Fugitive dust inhalation	2.0×10^{-14}	3.0×10^{-15}	2.1×10^{-14}	2.2×10^{-14}	6.8×10^{-13}	7.4×10^{-13}
Sum from All Pathways	6.7×10^{-8}	1.0×10^{-8}	7.1×10^{-8}	7.5×10^{-8}	2.3×10^{-6}	2.5×10^{-6}
INEEL worker						
Groundwater ingestion	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Soil ingestion	1.7×10^{-12}	2.6×10^{-13}	1.8×10^{-12}	1.9×10^{-12}	5.8×10^{-11}	6.4×10^{-11}
Skin absorption	2.4×10^{-10}	3.6×10^{-11}	2.5×10^{-10}	2.7×10^{-10}	8.2×10^{-9}	9.0×10^{-9}
Fugitive dust inhalation	5.0×10^{-14}	7.6×10^{-15}	5.3×10^{-14}	5.6×10^{-14}	1.7×10^{-12}	1.9×10^{-12}
Sum from All Pathways	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Construction worker						
Groundwater ingestion	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Soil ingestion	1.7×10^{-12}	2.6×10^{-13}	1.8×10^{-12}	1.9×10^{-12}	5.8×10^{-11}	6.4×10^{-11}
Skin absorption	2.4×10^{-10}	3.6×10^{-11}	2.5×10^{-10}	2.7×10^{-10}	8.2×10^{-9}	9.0×10^{-9}
Fugitive dust inhalation	5.0×10^{-14}	7.6×10^{-15}	5.3×10^{-14}	5.6×10^{-14}	1.7×10^{-12}	1.9×10^{-12}
Sum from All Pathways	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Indoor worker						
Groundwater ingestion	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Soil ingestion	8.4×10^{-13}	1.3×10^{-13}	9.0×10^{-13}	9.4×10^{-13}	2.9×10^{-11}	3.2×10^{-11}
Skin absorption	2.4×10^{-10}	3.6×10^{-11}	2.5×10^{-10}	2.7×10^{-10}	8.2×10^{-9}	8.9×10^{-9}
Fugitive dust inhalation	3.7×10^{-14}	5.7×10^{-15}	4.0×10^{-14}	4.2×10^{-14}	1.3×10^{-12}	1.4×10^{-12}
Sum from All Pathways	7.0×10^{-8}	1.1×10^{-8}	7.5×10^{-8}	7.8×10^{-8}	2.4×10^{-6}	2.6×10^{-6}
Unauthorized intruder						
Soil ingestion	3.8×10^{-16}	5.8×10^{-17}	4.0×10^{-16}	4.2×10^{-16}	1.3×10^{-14}	1.4×10^{-14}
Skin absorption	1.5×10^{-16}	2.3×10^{-17}	1.6×10^{-16}	1.7×10^{-16}	5.2×10^{-15}	5.7×10^{-15}
Fugitive dust inhalation	1.1×10^{-17}	1.7×10^{-18}	1.2×10^{-17}	1.2×10^{-17}	3.9×10^{-16}	4.2×10^{-16}
Sum from All Pathways	5.4×10^{-16}	8.2×10^{-17}	5.8×10^{-16}	6.0×10^{-16}	1.9×10^{-14}	2.0×10^{-14}

Table C.9-16. (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Uninformed intruder						
Soil ingestion	2.7×10^{-16}	4.1×10^{-17}	2.9×10^{-16}	3.0×10^{-16}	9.4×10^{-15}	1.0×10^{-14}
Skin absorption	1.1×10^{-16}	1.6×10^{-17}	1.2×10^{-16}	1.2×10^{-16}	3.7×10^{-15}	4.1×10^{-15}
Fugitive dust inhalation	7.9×10^{-18}	1.2×10^{-18}	8.5×10^{-18}	8.9×10^{-18}	2.8×10^{-16}	3.0×10^{-16}
Sum from All Pathways	3.9×10^{-16}	5.9×10^{-17}	4.1×10^{-16}	4.3×10^{-16}	1.3×10^{-14}	1.5×10^{-14}
Recreational user						
Groundwater ingestion	7.8×10^{-9}	1.2×10^{-9}	8.4×10^{-9}	8.7×10^{-9}	2.7×10^{-7}	2.9×10^{-7}
Soil ingestion	9.0×10^{-14}	1.4×10^{-14}	9.7×10^{-14}	1.0×10^{-13}	3.1×10^{-12}	3.4×10^{-12}
Food ingestion	3.0×10^{-10}	4.6×10^{-11}	3.2×10^{-10}	3.4×10^{-10}	1.0×10^{-8}	1.1×10^{-8}
Skin absorption	1.3×10^{-11}	2.0×10^{-12}	1.4×10^{-11}	1.5×10^{-11}	4.6×10^{-10}	5.0×10^{-10}
Fugitive dust inhalation	2.7×10^{-15}	4.1×10^{-16}	2.9×10^{-15}	3.0×10^{-15}	9.3×10^{-14}	1.0×10^{-13}
Sum from All Pathways	3.7×10^{-9}	1.2×10^{-9}	8.7×10^{-9}	9.1×10^{-9}	2.8×10^{-7}	3.1×10^{-7}

fluoride and nitrate intakes could be concurrent, and the health effects associated with these substances do not affect the same organ system. It is not appropriate, therefore, to assess the combined effects (hazard index) of these intakes.

In summary, the nonradiological health risk incurred under facility closure scenarios is dominated by fluoride intake. The estimated fluoride intake rate slightly exceeds the oral RfD for the maximally exposed resident; however this estimate is based on conservative assumptions and the limiting effect (objectionable dental fluorosis) is not considered an adverse health effect. DOE concludes, therefore, that no adverse nonradiological health effects are likely to arise under any of the closure scenario assessed here.

Table C.9-17. Noncarcinogenic health hazard quotient for fluoride by receptor category, principal intake pathway and facility disposition alternative.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer						
Groundwater ingestion	0.018	1.2×10^{-4}	0.026	0.06	0.31	0.32
Soil ingestion	5.8×10^{-7}	3.7×10^{-9}	8.5×10^{-7}	1.9×10^{-6}	1.0×10^{-5}	1.0×10^{-5}
Food ingestion	0.062	4.0×10^{-4}	0.091	0.21	1.1	1.1
Skin absorption	3.1×10^{-5}	2.0×10^{-7}	4.5×10^{-5}	1.0×10^{-4}	5.4×10^{-4}	5.5×10^{-4}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from all pathways	0.08	5.2×10^{-4}	0.12	0.27	1.4	1.4
Average resident farmer						
Groundwater ingestion	9.8×10^{-3}	6.4×10^{-5}	0.014	0.033	0.17	0.18
Soil ingestion	1.7×10^{-7}	1.1×10^{-9}	2.5×10^{-7}	5.7×10^{-7}	3.0×10^{-6}	3.0×10^{-6}
Food ingestion	0.03	1.9×10^{-4}	0.044	0.099	0.52	0.53
Skin absorption	1.7×10^{-5}	1.1×10^{-7}	2.5×10^{-5}	5.6×10^{-5}	3.0×10^{-4}	3.0×10^{-4}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	0.04	2.6×10^{-4}	0.058	0.13	0.69	0.71
INEEL worker						
Groundwater ingestion	6.4×10^{-3}	4.1×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Soil ingestion	1.5×10^{-7}	1.0×10^{-9}	2.3×10^{-7}	5.1×10^{-7}	2.7×10^{-6}	2.8×10^{-6}
Skin absorption	1.8×10^{-5}	1.2×10^{-7}	2.7×10^{-5}	6.0×10^{-5}	3.2×10^{-4}	3.2×10^{-4}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	6.4×10^{-3}	4.2×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Construction worker						
Groundwater ingestion	6.4×10^{-3}	4.1×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Soil ingestion	1.5×10^{-7}	1.0×10^{-9}	2.3×10^{-7}	5.1×10^{-7}	2.7×10^{-6}	2.8×10^{-6}
Skin absorption	1.8×10^{-5}	1.2×10^{-7}	2.7×10^{-5}	6.0×10^{-5}	3.2×10^{-4}	3.2×10^{-4}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	6.4×10^{-3}	4.2×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Indoor worker						
Groundwater ingestion	6.4×10^{-3}	4.1×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Soil ingestion	1.5×10^{-7}	8.6×10^{-10}	1.6×10^{-7}	2.6×10^{-7}	1.4×10^{-6}	1.4×10^{-6}
Skin absorption	1.8×10^{-5}	1.2×10^{-7}	2.7×10^{-5}	6.0×10^{-5}	3.2×10^{-4}	3.2×10^{-4}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	6.4×10^{-3}	4.2×10^{-5}	9.4×10^{-3}	0.021	0.11	0.11
Unauthorized intruder						
Soil ingestion	8.7×10^{-10}	5.6×10^{-12}	1.3×10^{-9}	2.9×10^{-9}	1.5×10^{-8}	1.5×10^{-8}
Skin absorption	1.2×10^{-11}	7.5×10^{-14}	1.4×10^{-11}	3.3×10^{-11}	2.0×10^{-10}	2.1×10^{-10}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	8.8×10^{-10}	5.7×10^{-12}	1.3×10^{-9}	2.9×10^{-9}	1.5×10^{-8}	1.6×10^{-8}

Table C.9-17. (continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Uninformed intruder						
Soil ingestion	6.2×10^{-10}	4.0×10^{-12}	1.1×10^{-9}	2.5×10^{-9}	1.1×10^{-8}	1.1×10^{-8}
Skin absorption	8.2×10^{-12}	5.3×10^{-14}	1.5×10^{-11}	3.3×10^{-11}	1.4×10^{-10}	1.5×10^{-10}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	6.3×10^{-10}	4.1×10^{-12}	1.1×10^{-9}	2.5×10^{-9}	1.1×10^{-8}	1.1×10^{-8}
Recreational user						
Groundwater ingestion	6.9×10^{-4}	4.5×10^{-6}	1.0×10^{-3}	2.3×10^{-3}	0.013	0.013
Soil ingestion	8.7×10^{-9}	5.6×10^{-11}	1.3×10^{-8}	2.9×10^{-8}	1.5×10^{-7}	1.5×10^{-7}
Food ingestion	1.1×10^{-3}	7.0×10^{-6}	1.6×10^{-3}	1.8×10^{-3}	0.019	0.019
Skin absorption	1.0×10^{-6}	6.6×10^{-9}	1.5×10^{-6}	3.4×10^{-6}	1.8×10^{-5}	1.8×10^{-5}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	1.8×10^{-3}	1.2×10^{-5}	2.6×10^{-3}	4.1×10^{-3}	0.032	0.032

Table C.9-18. Noncarcinogenic health hazard quotient for nitrate by receptor category, principal intake pathway and facility disposition alternative.

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Maximally exposed resident farmer						
Groundwater ingestion	1.1×10^{-3}	5.2×10^{-6}	2.0×10^{-5}	2.0×10^{-5}	5.2×10^{-6}	5.2×10^{-6}
Soil ingestion	3.6×10^{-8}	1.7×10^{-10}	6.4×10^{-10}	6.4×10^{-10}	1.7×10^{-10}	1.7×10^{-10}
Food ingestion	5.3×10^{-3}	2.5×10^{-5}	0.000094	9.4×10^{-5}	2.5×10^{-5}	2.5×10^{-5}
Skin absorption	1.9×10^{-6}	8.9×10^{-9}	3.4×10^{-8}	3.4×10^{-8}	8.9×10^{-9}	8.9×10^{-9}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from all pathways	6.5×10^{-3}	3.0×10^{-5}	1.1×10^{-4}	1.1×10^{-4}	3.0×10^{-5}	3.0×10^{-5}
Average resident farmer						
Groundwater ingestion	6.2×10^{-4}	2.9×10^{-6}	1.1×10^{-5}	1.1×10^{-5}	2.9×10^{-6}	2.9×10^{-6}
Soil ingestion	1.1×10^{-8}	4.9×10^{-11}	1.9×10^{-10}	1.9×10^{-10}	4.9×10^{-11}	4.9×10^{-11}
Food ingestion	2.2×10^{-3}	1.0×10^{-5}	3.9×10^{-5}	3.9×10^{-5}	1.0×10^{-5}	1.0×10^{-5}
Skin absorption	1.1×10^{-6}	4.9×10^{-9}	1.9×10^{-8}	1.9×10^{-8}	4.9×10^{-9}	4.9×10^{-9}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	2.9×10^{-3}	1.3×10^{-5}	5.0×10^{-5}	5.0×10^{-5}	1.3×10^{-5}	1.3×10^{-5}
INEEL worker						
Groundwater ingestion	4.0×10^{-4}	1.9×10^{-6}	7.0×10^{-6}	7.0×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Soil ingestion	9.7×10^{-9}	4.5×10^{-11}	1.7×10^{-10}	1.7×10^{-10}	4.5×10^{-11}	4.5×10^{-11}
Skin absorption	1.1×10^{-6}	5.3×10^{-9}	2.0×10^{-8}	2.0×10^{-8}	5.3×10^{-9}	5.3×10^{-9}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	4.0×10^{-4}	1.9×10^{-6}	7.1×10^{-6}	7.1×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Construction worker						
Groundwater ingestion	4.0×10^{-4}	1.9×10^{-6}	7.0×10^{-6}	7.0×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Soil ingestion	9.7×10^{-9}	4.5×10^{-11}	1.7×10^{-10}	1.7×10^{-10}	4.5×10^{-11}	4.5×10^{-11}
Skin absorption	1.1×10^{-6}	5.3×10^{-9}	2.0×10^{-8}	2.0×10^{-8}	5.3×10^{-9}	5.3×10^{-9}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	4.0×10^{-4}	1.9×10^{-6}	7.1×10^{-6}	7.1×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Indoor worker						
Groundwater ingestion	4.0×10^{-4}	1.9×10^{-6}	7.0×10^{-6}	7.0×10^{-6}	1.9×10^{-6}	1.9×10^{-6}
Soil ingestion	4.8×10^{-9}	2.2×10^{-11}	8.5×10^{-11}	8.5×10^{-11}	2.2×10^{-11}	2.2×10^{-11}
Skin absorption	1.1×10^{-6}	5.3×10^{-9}	2.0×10^{-8}	2.0×10^{-8}	5.3×10^{-9}	5.3×10^{-9}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	4.0×10^{-4}	1.9×10^{-6}	7.1×10^{-6}	7.1×10^{-6}	1.9×10^{-6}	1.9×10^{-6}

Table C.9-18. (Continued).

Exposure scenario and pathway	No Action	Performance-Based Closure/ Closure to Landfill Standards	Performance-Based Closure with Class A Grout Disposal	Performance-Based Closure with Class C Grout Disposal	Disposal of Class A grout in low-activity waste disposal facility	Disposal of Class C grout in low-activity waste disposal facility
Unauthorized intruder						
Soil ingestion	5.4×10^{-11}	2.5×10^{-13}	9.5×10^{-13}	9.5×10^{-13}	2.5×10^{-13}	2.5×10^{-13}
Skin absorption	7.2×10^{-13}	3.4×10^{-15}	1.3×10^{-14}	1.3×10^{-14}	3.4×10^{-15}	3.4×10^{-15}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	5.5×10^{-11}	2.6×10^{-13}	9.7×10^{-13}	9.7×10^{-13}	2.6×10^{-13}	2.6×10^{-13}
Uninformed intruder						
Soil ingestion	3.9×10^{-11}	1.8×10^{-13}	6.8×10^{-13}	6.8×10^{-13}	1.8×10^{-13}	1.8×10^{-13}
Skin absorption	3.9×10^{-11}	3.1×10^{-15}	1.1×10^{-14}	1.1×10^{-14}	3.1×10^{-15}	3.1×10^{-15}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	7.7×10^{-11}	1.8×10^{-13}	6.9×10^{-13}	6.9×10^{-13}	1.8×10^{-13}	1.8×10^{-13}
Recreational user						
Groundwater ingestion	4.3×10^{-5}	2.0×10^{-7}	7.6×10^{-7}	7.6×10^{-7}	2.0×10^{-7}	2.0×10^{-7}
Soil ingestion	5.4×10^{-10}	2.5×10^{-12}	9.5×10^{-12}	9.5×10^{-12}	2.5×10^{-12}	2.5×10^{-12}
Food ingestion	4.1×10^{-5}	1.9×10^{-7}	7.3×10^{-7}	7.3×10^{-7}	1.9×10^{-7}	1.9×10^{-7}
Skin absorption	6.1×10^{-8}	2.8×10^{-10}	1.1×10^{-9}	1.1×10^{-9}	2.8×10^{-10}	2.8×10^{-10}
Fugitive dust inhalation	-	-	-	-	-	-
Sum from All Pathways	8.4×10^{-5}	3.9×10^{-7}	1.5×10^{-6}	1.5×10^{-6}	3.9×10^{-7}	3.9×10^{-7}

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